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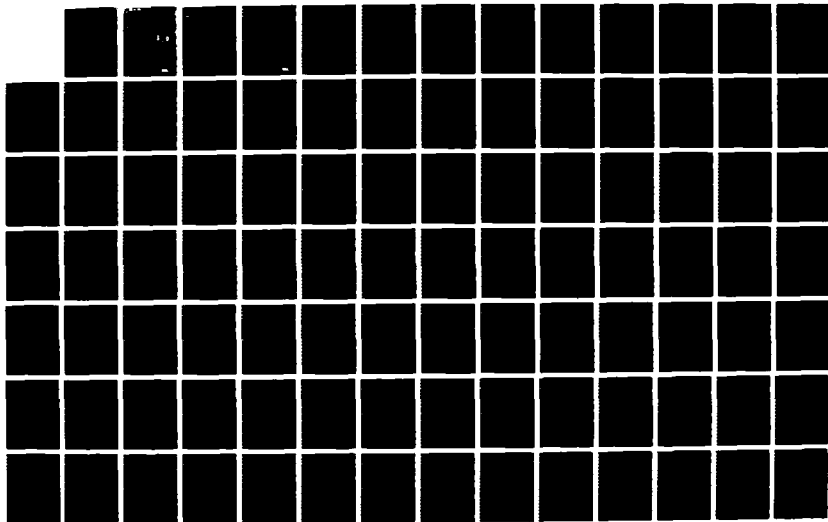
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NON-IONIZING ELECTR. (U) RESEARCH AND DEVELOPMENT LABS
CULVER CITY CA NOV 87 RDL-27 N00039-86-C-0136

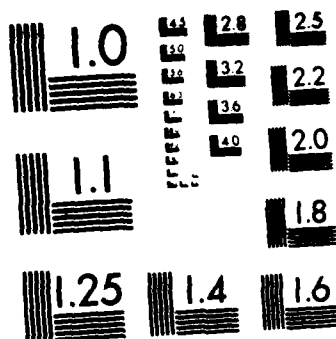
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RDL Report No. 27

EXTREMELY LOW FREQUENCY (ELF) COMMUNICATIONS PROGRAM
NON-IONIZING ELECTROMAGNETIC RADIATION
LITERATURE EVALUATION AND ASSESSMENT

1986-1987 Literature Review
Final Report

November 1987

Prepared for:

Department of the Navy
Space and Naval Warfare Systems Command
Washington, D.C. 20363-5100

Prepared by:

Research & Development Laboratories
5721 West Slauson Avenue
Culver City, California 90230-6509

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CHAPTER 1

OVERVIEW, SUMMARY, AND CONCLUSIONS

1.1 Overview

→ This report represents the Second Final Report prepared by the staff of Research and Development Laboratories (RDL) for presentation to the Department of the Navy (Space and Naval Warfare Systems Command), dealing with the evaluation and assessment of literature concerned with the bioeffects of Extremely Low Frequency Electromagnetic Radiation. The report covers the period from November 1986 to October 1987.

The objective of this program is to conduct a thorough and comprehensive review, ^{and} evaluation, and assessment of the published professional literature containing scientific information pertaining to biological effects, including but not limited to human health effects of nonionizing electromagnetic radiation, germane to the Extremely Low Frequency (ELF) Communications Program of the United States Navy.

The published professional literature reviewed, evaluated and assessed includes books, research reports, project reports, and articles and papers in peer-reviewed journals that discuss and/or describe biological and health effects of nonionizing electromagnetic radiation in the frequency range of 1- 300 Hz. In some instances documents discussing effects of frequencies above 300 Hz were also reviewed if, in the opinion of the reviewer, the scientific information was important to understanding the issues under consideration. The review and evaluation included both

3- + d
→ domestic and international literature published in English or other foreign languages. ←

This task provides a continuation of the previous efforts by the National Academy of Sciences (NAS) and the American Institute of Biological Sciences (AIBS) to systematically document and evaluate all information on the bioeffects of Extremely Low Frequency Electromagnetic Radiation. The NAS report entitled "Biological Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer" was published in 1977 and covered the literature up to 1977. This was followed by the AIBS report entitled "Biological and Human Health Effects of Extremely Low Frequency Electromagnetic Fields" which covered the literature up to March 1984. The library listing of January 7, 1985, for Biological Effects of ELF Electromagnetic Fields for the period of 1977 to March 1984, developed by IIT Research Institute (1985) and the relevant literature published throughout the period of April 1985 to March 1986 were evaluated and presented in RDL Report No. 26 to the Department of the Navy in November 1986.

The major conclusions of each of these reports were as follows :

NAS report "Biological Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer" indicated that electric and magnetic fields associated with the Navy's ELF Communication System "... will not cause a significant and adverse biological disturbance, except in the event of electric shock.....".

AIBS report "Biological and Human Health Effects of Extremely Low Frequency Electromagnetic Fields" concluded that "...it is unlikely that exposure of living systems to ELF electric and magnetic fields in the range of those associated with the Navy's ELF Communication System

can lead to adverse public health effects or to adverse effects on plants and animals".

RDL Report No. 28, "Extremely Low Frequency (ELF) Communications Program : Non-Ionizing Electromagnetic Radiation Literature Evaluation and Assessment - Final Report, November 1986" , concluded that, "It is unlikely that electric and magnetic fields associated with the ELFCS have an adverse effect on human health or on animal systems in general".

As will become apparent, these overall conclusions have not changed based on the review of literature that has been assessed over the last 11 months. Chapter 1 of this report presents brief summaries for eight different and, in our opinion, the most important issue areas associated with the ELF electric and magnetic field bioeffects. These general issue areas are :

- o Physical Hazards Including Electric Shocks and Effects on Electronic Medical Devices
- o Therapeutic Effects
- o Cellular and Physiological Studies
- o Metabolism, Growth and Development
- o Reproductive Effects
- o Cancer Risk
- o Behavioral Effects
- o Ecological Effects

The summaries are based solely on the results of evaluations of nearly four hundred citations which appeared in the professional literature and were retrieved by RDL and its consultants up to the period of August 1987. The overall conclusion at the end of Chapter 1 integrates all of the summaries into one compact statement on the status of current scientific knowledge of the possible effects of ELF electric and magnetic fields on living systems exposed to these fields.

One of the tasks of the ELF Communication Program is the development of an ELF Bioeffects Library, an integral part of which is the development of a data base computer file. RDL has developed and continues to update two separate data base computer files capable of delivering bibliographic records of all relevant literature retrieved by IIT Research Institute and RDL, respectively. These data bases allow one to search for a particular citation based on such information as Title, Author's name, Source, Author's Institutional affiliation, and Index Number. A detailed description of the ELF Bioeffects Libraries, including data base computer file features and operation, is presented in Chapter II.

Chapter III presents details on the review, evaluation and assessment procedures.

Chapter IV presents a more thorough discussion of the evaluated and assessed literature used in preparation of the summary in Chapter I. The review is confined to the same categories as those outlined in Chapter I.

1.2. Summaries And Conclusions

Physical Hazards, Including Electric Shocks and Effects on Electronic Medical Devices

The two principal physical effects of ELF electric and magnetic fields that are potentially harmful to humans are the influence of these fields on implanted medical devices such as cardiac pacemakers, and electric shocks and spark discharges delivered from charged metal objects in the vicinity of a high-voltage source. Pacemaker sensitivity results from electromagnetic interference (EMI) that can produce malfunctions characterized by either an aberrant pacing rate or a reversion to a fixed-rate pacing mode. The latter type of malfunction can lead to pacemaker stimuli that are competitive with the heart's endogenous firing rate. Problems with EMI are limited to pacemakers of the "unipolar" design, which forms a large antenna loop between the cathode lead that is implanted in the heart and the case of the pacemaker, which serves as the anode. Approximately 250,000 people in the United States have implanted pacemakers of the "unipolar" design. Research reports reviewed by RDL during the past year have identified numerous sources of the pacemaker EMI in hospitals, in occupational settings and in the public domain. However, based on extensive study of pacemaker patients in England, remarkably few incidences were documented of adverse effects of EMI on pacemaker operation. In other studies, the vulnerability of various types of pacemakers to EMI was characterized. The threshold electric field level that causes pacemaker malfunctioning was confirmed to be approximately 2 kV/m, which is more than an order of magnitude greater than the maximum field in air in the vicinity of an ELF antenna (160 V/m). It can be concluded that no pacemaker-related

problems should result from human exposure to the fields associated with an ELF communication system. A similar conclusion can be drawn for the risk of electric shocks and spark discharges resulting from the contact of humans or lower animal species with metallic objects in the vicinity of an ELF antenna.

Therapeutic Effects

A large number of clinical trials have demonstrated that pulsed magnetic fields with ELF repetition frequencies facilitate bone fracture reunion. These fields are applied by external Helmholtz coil applicators placed about the limb containing a bone fracture, and the electric currents thereby induced in the region of the fracture are responsible for the accelerated healing that is observed. The articles reviewed by RDL staff and consultants during the past year have continued to confirm the efficacy of using pulsed magnetic fields to facilitate bone fracture healing. Laboratory studies with experimental animals have also indicated that pulsed fields may be beneficial in promoting the healing of soft tissue injuries. Several in vitro studies on bone cells and other types of tissue cells have indicated that exposure to ELF pulsed fields leads to an enhancement of protein synthesis and cell proliferation. Overall, the results of the in vivo and in vitro laboratory studies are consistent in predicting that pulsed fields should facilitate bone growth in the region of a fracture. The magnetic field intensities that produce these effects, however, are more than 100 times greater than the maximum 72 to 80 Hz magnetic fields present in air in the vicinity of an ELF antenna.

Cellular and Physiological Studies

The literature reviewed on cellular, cell membrane, tissue, and whole animal interactions with electric and magnetic fields may be grouped into cell biology studies, genetics studies, studies of calcium-related phenomena, neurophysiological, neuroendocrine and physiological studies. In particular, the cell biology studies commonly tested for biochemical responses, while the in vitro cellular genetics studies involved gene transcription and translation. Genetic studies in the whole animal tested chromosomal and reproductive endpoints. The calcium studies, sometimes in relation to the "cyclotron resonance" model, tested frequency- and field strength-specific effects.

Overall, the research has been marked by data which indicate that relatively weak low frequency magnetic fields in the range of 0.5 - 20 mG have significant effects on cell functions. Many investigators also found that exposure-response relations were complex, supporting the concept of frequency or amplitude windows, although overall, the windows are often inconsistent from one study to another. In the main, the results of the last twelve months have augmented previous research directions rather than striking out in new directions. Because the mechanisms of interaction are largely unknown, and because of the complicated dosimetric patterns, it is significant that many of the unusual characteristics reported in previous years has been supported by more work, thereby strengthening the data base. Although recent epidemiological data suggest that very weak (1 mG) sinusoidal magnetic fields may influence the development of cancers, there have been no studies conducted at that level. However, the magnetic fields near an ELFCS antenna are several orders of magnitude

larger, and experiments with magnetic fields of 0.1 and 1 mT are generally relevant to the ELFCS.

The literature reviews in 1987 included a greater number of citations from East European countries, including the USSR. Many of these studies appear to involve strong (0.01 to 1 T) static magnetic fields and powerline magnetic fields.

In summary, the research into cellular and biochemical effects tends to support the principle that weak ELF fields interact with fundamental cell processes and suggests pathological or beneficial effects are possible from in vivo exposures. However, recent reports on animal experimentation, provide evidence for strong effects in vivo in only a few models. These include loss of the pineal melatonin rhythm and altered brain amines in rats exposed to 60-Hz electric fields, developmental defects in chicks exposed to pulsed magnetic fields, and possible developmental defects in 60-Hz electric field exposed swine.

Metabolism, Growth and Development

The literature reviewed on effects of electromagnetic fields on metabolism, growth and development of living organisms, revealed ambiguity. Studies from different laboratories produced conflicting data. In some studies significant effects of electromagnetic fields on metabolic parameters could only be shown when the sample number was very large, suggesting that the differences observed were too close to being insignificant. Earlier studies which had shown an effect of non-ionizing radiation on calcium efflux from chick brains were reproduced by some laboratories but not by others. No detrimental effects were observed on the immune system.

Two citations reported abnormal fetal development when embryos were exposed to 100 Hz electromagnetic fields. However two other reports were unable to corroborate this data. Studies of growth related enzymes like phenylalanine ammonia-lyase in plants, and ornithine decarboxylase in animal cells showed an increase in the enzyme activities after exposure to ELF fields. Other studies reported a stimulation of prostacyclin levels in aortas (which could be used beneficially in a clinical setting), and decreases in cAMP and cAMP dependent protein kinase activities. These changes corresponded with changes in phosphorylation of certain proteins. However, the physiological significance of these changes has not been established. Based on the literature reviewed to date, it can be concluded that ELF electric and magnetic fields in the range associated with the ELFCS have not been demonstrated to produce adverse metabolic, growth, or developmental effects in animal systems.

Reproductive Effects

Studies of potential reproductive effects of ELF electromagnetic fields continue to receive much greater attention from laboratory scientists than from epidemiologists. The basis for this is the relative absence of epidemiologic data regarding reproductive damage. The only human studies of reproduction noted in this year's literature were relatively minor, and reported second-hand that an increase in miscarriages was noted in operators of Video Display Terminals (VDT), and a translated abstract expressed concerns of sudden infant death and proximity to electrical lines. Studies of the reproductive performance of dairy cows in the vicinity of AC power lines found no indication of diminished performance. Other studies on chick embryo

development following exposure to electromagnetic radiation reported conflicting data.

In view of the limited studies and the data reported during the past twelve month period, the conclusions presented in 1986 Final Report remain valid i.e., evidence of adverse effects of ELF fields on reproduction is unconvincing.

Cancer Risk

Several papers considered the relationship between residential exposure to electromagnetic fields from outside power lines and the occurrence of childhood cancer. Apart from one study of childhood cancer in Sweden which provided evidence of increased cases of cancer in the vicinity of transmission lines, the majority of reports were inconsistent. The impression that there is a non-random pattern of elevated brain cancer and leukemia among workers potentially exposed to electromagnetic fields continues to be strengthened. Although there were no "breakthrough" studies of carcinogenic effects of ELF electromagnetic fields, the literature grew in epidemiologic studies of residential and occupational exposures and in laboratory investigations of the effects of such fields on cellular processes related to cancer. Overall, the possibility that cancer risk is increased was enhanced rather than diminished by the studies summarized in this section.

Behavioral Effects

Most of the citations reviewed with regard to behavioral effects resulting from exposure to ELF fields during this review period were primarily abstracts of papers presented at meetings and/or work in progress. While critical reviews could not be done, the results claimed support for the

contention that EMFs in the vicinity of ELFCSs are unlikely to produce adverse behavioral effects. Studies carried out under the sponsorship of the US Department of Energy using primates defined threshold levels to induce avoidance-escape responses. Exposure of baboons to 60 Hz EMF fields did not affect appetite or operant behavior. Stress related behaviors exhibited by baboons exposed to 60 Hz, 30 kV/m fields were only transitory, while there was no effect on postural adjustments. Other studies using rats similarly reported no effect of exposure on taste-aversion learning.

Results from studies of orientation and homing responses of pigeons and bees suggest that it is unlikely that EMF in the vicinity of ELFCS sites will interfere with the normal homing ability of small animals since homing and navigation are apparently redundant processes using several environmental cues.

Ecological Effects

A number of studies dealing with ecological effects of EMFs in the vicinity of high voltage transmission lines and around ELFCS antenna are under way at the moment. Thus the reports on these studies are still incomplete. Studies on the effect of fields generated around high voltage transmission lines to date have shown no harmful effects on agriculture or livestock. Furthermore, most of these studies are done at EMFs of much higher intensities than those which occur at ELF communication sites. One opinion that has developed from studies in the vicinity of the ELFCS antenna regarding ecological impact is that detectable ecological effects of ELFCSs will likely be from construction and maintenance of right-of-way corridors rather than from the ELF fields.

Most of the citations summarized were abstracts. While a critical review was not done, some general observations seem justified. First, an international awareness and concern over the possible biological effects of non-ionizing EMF persists. Second, the suggested threshold for producing biological effects in the immediate vicinity of transmission line right-of- ways is 2.5 kV/m which is significantly greater than EMFs observed at ELF communication sites. Third, the public perception of potential hazards from EMF remain difficult to alleviate in light of disagreement between scientists as to the reality of the threat.

1.3. Overall Conclusions

The following general conclusions can be drawn from the review of literature on the biological effects of ELF electric and magnetic fields that was conducted by RDL staff and consultants during the past year:

- o Research with laboratory animals and limited human studies have not demonstrated significant physiological or behavioral effects of ELF fields with intensities comparable to those of an ELF communication system. At electric field strengths approximately two orders of magnitude higher than those produced by an ELF antenna, minor aversive behavioral changes have been noted. These changes, however, are transitory in nature. Effects of ELF fields on animal development and neurochemistry have been reported, although the reproducibility of these experiments has not been firmly established. A major study on the growth, development, and health rhesus monkeys exposed chronically to fields matching those of an ELF antenna led to the conclusion that these fields have not shown any adverse effects.

- o Pulsed fields with ELF repetition frequencies and high peak intensities have been shown in a large number of clinical trials to facilitate bone fracture reunion. Preliminary data also suggests that such fields may be beneficial in promoting the healing of soft tissue injuries. Laboratory studies indicate that these effects of pulsed fields may result from the stimulation of protein synthesis (e.g., collagen) and cell proliferation. However, these effects have not been consistently observed in experiments conducted in different laboratories.

- o In vitro studies conducted with field levels much higher than those associated with an ELF antenna have demonstrated effects on cell growth, on metabolism (e.g., effects on cellular phosphorylation mechanisms), and on DNA synthesis, transcription, and translation. Although the threshold field levels required to produce these cellular effects have not been established in all cases, they are generally higher than the maximum electric and magnetic fields associated with an ELF communications system.

- o Present evidence indicates that no adverse ecological effects should result from exposure to fields with intensities as low as those associated with ELF antennas. A number of research reports indicate that migratory birds can detect fields of this magnitude, but there is no indication that the long-range migratory patterns of avians are altered by their sensitivity to ELF fields. There is also no convincing evidence that agricultural crops or livestock are adversely affected by these fields.

- o Cardiac pacemakers of the "unipolar" design have been shown to be

highly sensitive to electromagnetic interference from ELF electric and magnetic fields, but the threshold field intensities required to produce pacemaker malfunctions are higher than the intensities of ELF antenna fields.

o No significant effects of ELF fields on reproductive functions have been documented. A recent report that the use of electric blankets and electrically heated waterbeds leads to an increased gestation time and an increased incidence of abortions is highly questionable since the confounding effects of excessive heating were not adequately accounted for.

o Epidemiological studies on the correlation between human exposure to residential ELF fields and cancer incidence led to the contradictory findings of a positive correlation in two studies, no correlation in two other studies, and equivocal results in a fifth study. Mixed positive and negative findings also were reported in studies on the possible relationship between occupational exposure to ELF fields and the incidence of leukemia and brain tumors. At the present time, the evidence linking cancer incidence to excessive ELF field exposure is circumstantial, and additional epidemiological studies are needed in order to resolve this issue.

Based on the review and evaluation of the available professional literature published in the period November 1986 to October 1987 containing scientific information relevant to biological and health effects of ELF electromagnetic radiation, the overall conclusion is that :

It is unlikely that ELF electric and magnetic fields associated with the ELFCS have an adverse effect on human health or on animal systems in general.

CHAPTER II

LIBRARY DEVELOPMENT

The basic components of Library Development for the ELF Bioeffects Literature Evaluation and Assessment Program are: literature searches of appropriate information data bases, culling and indexing of retrieved relevant literature, translation of relevant foreign documents, entry of bibliographic and characterization information into a data base computer file, and storage of bioeffects literature in a permanent library. The specifics of each of these ELF Library components have been described in detail from their initial development through completion in the various monthly progress reports published by RDL beginning in December 1985. Following is a summary of the library components.

2.1. Literature Search and Retrieval

RDL began development of the bioeffects literature search strategy by identifying information data bases likely to contain the majority of literature related to the subject of interest. Through Dialog Information Systems, Inc. of Palo Alto, California, 26 data bases were initially identified as viable candidates. RDL then began consultations with Information on Demand, Inc. of Berkeley, California for development of an effective and comprehensive literature search strategy. Literature searches continue to be conducted at the same twenty (20) information data bases as reported in the 1986 Final report. These are :

- o Aerospace Data Base
- o Agricola
- o Biosis Preview
- o CAB Abstracts
- o Compendex
- o Conference Papers Index
- o Dissertation Abstracts Online
- o DOE Energy
- o DTIC
- o EI Engineering Meetings
- o Electric Power Data Base
- o Embase Excerpta Medica
- o Energyline
- o Enviroline
- o Environmental Bibliography
- o INSPEC
- o LC MARC
- o NIOSH
- o NTIS
- o Pollution Abstracts

Literature search and document retrieval have been completed for the period up to August 1987. Approximately 575 citations were returned from the searches. Of these, twenty (20) percent were eliminated as not relevant, and an additional five

(5) percent were eliminated due to inter-data base redundancy. A net total of 430 relevant and new citations were realized during the November 1986-August 1987 time frame. Of these, 382 relevant citations have been reviewed by RDL staff and consultants, and reported in the Monthly Progress Reports ending September 1987. Others await evaluation.

Actual retrieval of relevant documents has been accomplished through a variety of sources. Primary sources include the University of California, Los Angeles; California Institute of Technology; the Foreign Broadcast Information Service; Joint Publications Research Service; various professional journals and publications in the field of bioelectromagnetics; as well as contributions from RDL's technical experts in the various fields associated with bioelectromagnetic effects and research.

2.2. Literature Culling and Indexing

All relevant bioeffects literature recovered from the literature searches was prepared for inclusion into a data base computer file (developed specifically for this program by RDL). In addition to all required bibliographic data, each document has been characterized by Subject Category, Subject Material, Issue Area, Electromagnetic Field Type, Electromagnetic Field Characterization, and Species Type. The specific key words and descriptors for each of these data fields were developed in cooperation with library specialists, RDL's experts in bioelectromagnetics, and with emphasis on the continuation of criteria established by the AIBS and the NAS. Lists of all key words in the various data fields were submitted for approval to the ELF Project Office. The characterizations and bibliographies of all retrieved bioeffects literature are resident within the RDL data base computer file for use by the ELF Project Office or their designates. Specific details of the data base computer file have been published in RDL monthly progress reports, and are summarized below in Section 2.4.

2.3. Foreign Literature Translation

For that literature identified as new and relevant from the search of information data bases and other sources, RDL employed a number of resources to acquire English translations of those documents that showed potential for "new and significant findings" as directed by the Statement of Work. The initial resource was the Foreign Broadcast Information Service (FBIS). The FBIS is a body of the Government's Joint Publications Research Service (JPRS). Both FBIS and JPRS regularly translate foreign publications of interest in a variety of defense, technical, and medical fields. In the event that documents of interest were unavailable from FBIS/JPRS, they were translated by competent RDL staff members, or independent translation services.

2.4. Database Computer File Development

Introduction

This document describes the ELF Bioeffects Library Data Base System. The system has been developed by RDL to facilitate the efficient storage and retrieval of ELF biological effects literature. The system has been developed with the following criteria in mind:

- o efficient data access
- o ease of use
- o minimal learning time
- o portability

RDL has developed a Dedicated Data Base Management System, specifically designed for performing bibliographic literature searches. In evaluating many commercially available data base management systems, we have found none that effectively meet this requirement. Following is a description of the ELF Library Data Base, the User Interface, and the Search and Display Module of the Data Base System.

Data Base Description

The ELF Library Data Base is divided into the following categories and data fields:

- o ELF File Number;
- o Bibliographic Data--Author(s), Title, Publication Date, Author Affiliation, Report Number, Publication, Language, Number of Pages, Number of References;

o Keyword Data--EM Field Type, EM Field Characterization, Subject Categories, Subject Materials, Issue Areas, and Species.

Physically, the ELF data base is stored as a keyed ASCII text file. Each data record (single bibliographic entry) is delimited by a single line with an exclamation mark, followed by the record data. Fields are lines of text beginning with a percent character "%" and a unique 2-character field key. This method of storage allows for variable length fields, each field taking up exactly as much storage as needed, with a 3-byte per line overhead of the field key. This scheme allows for multiple author and keyword fields per record, as well as title fields of arbitrary length; for example:

```
%FN 85500
%AU Bernhardt JH, Kossel F
%TI Recommendations for the Safe Use of NMR Equipment
%DA Feb 1985
%AA Inst. for Radiation Hygiene, Federal Health Office,
%AA D-8042 Neuherberg, FRG
%PU Clin. Phys. Physiol. Meas., 1985, Vol. 6 No. 1,
%PU p. 65-74
%LA english
%NP 10p
%NR 0
%FT magnetic, electromagnetic
%FC 10Hz to 15Hz, 0.5T to 2T
%SM general health, cardiovascular effects
%SC public health, in-vivo exposure
%IA health risk, cardiac pacemakers, epilepsy, current
%IA density, nuclear magnetic resonance (NMR) systems,
%IA tomography
%SP humans
!
%FN 85501
%AU Fuhr G, Hagedorn R, Muller TH
%TI Cell Separation by Using Rotating Electric Fields
%DA 1985
```

See the figure on the following page for an example of a completed record.

File Number: 87038

Author(s): Gaffey, C., Tenforde, T.,

Title: Blood Flow Rate in the Rat's Carotid Artery During Exposure to Static Magnetic Fields

Publication Date: June 1987

Author's Affiliation: Lawrence Berkeley Lab., Univ. CA, Berkeley, CA 94720

Publication: The Bioelectromagnetic Society (Nineth Annual Meeting) 1987

Language: English No. Pages: Abstract

Field Type: Magnetic

Field Characterization: 1.5 Tesla

Subject Categories: In vitro exposure; physiological effects

Subject Materials: Cardiovascular effects

Issue Areas: Blood flow

Species: Rodents

File Number: 85563

Author(s): Gaito, J.

Title: The Suppression of Kindling with Low-Frequency Brain Stimulation: Statistical Data with Duration Variable

Publication Date: 1985

Author's Affiliation: Unspecified

Publication: Bulletin of the Psychonomic Soc., 23 (4), pp 332-334

Language: English No. Pages: 2 No. References: 9

Field Type: Electric

Field Characterization: 1, 3; 60 Hz

Subject Categories: Behavioral effect

Subject Materials: Behavior

Issue Areas: Kindling

Species: unspecified

Since the data base is stored as a text file, modifications and additions may be made using any standard text editor or word processor. Data may be easily transferred to other systems since the data base is not in any special binary format.

In order to provide immediate retrieval of data, it is necessary to index some of the fields that are frequently accessed when searching the data base. This is accomplished by using B-Tree indices (an efficient file indexing scheme) on the file number, author, and keyword fields. In a file with 160,000 records, an indexed search would require at most five disk accesses, as opposed to sequentially reading the entire data base.

User Interface

The ELF Library Data Base User Interface is designed for ease of use and requires minimal learning time. A menu-driven interface is used to provide quick and easy access to all ELF data base functions, at a single keystroke. The main menu provides the following functions:

```
-- Data Base: rdl ** ELF Bio-Effects Library ** main.menu --
```

```
* ELF Bio-effects Library Data Base - Main Menu *
```

Enter one of the following:

- S. Search Commands Menu
- C. Change Working Data Base
- A. Add Records to Data Base
- L. List Entire Data Base
- E. Expert Command Mode
- Q. Quit Elf Bio-Lib

Enter Menu Option Letter -- (?=Help, !=Main Menu) ->

Options are selected by pressing the letter on the keyboard corresponding to the function on the menu. Entering "S" will display the search commands

menu, "C" will allow the user to use a different database, "A" will allow the user to add records to the current database, etc. The search commands menu allows the user to access most of the fields in the ELF data base:

```
-- Data Base: rdl ** ELF Bio-Effects Library ** search.menu --
```

```
* ELF Bio-effects Library Data Base - Search Menu *
```

Search on the Following:

N. File Number	E. EM Field Type
A. Author Name	F. Field Characterisation
T. Title	S. Species
M. Subject Materials	D. Publication Date
C. Subject Categories	I. Author Affiliation
I. Issue Areas	Q. Quit Search Menu

Enter Menu Option Letter -- (?=Help, !=Main Menu) ->

An expert command mode is provided for users who are more experienced and prefer a command-driven interface to a menu interface. Searches that do not appear on the search command menu may be performed using the command-driven interface.

Searching and Displaying the Data Base

When a search is performed on the ELF data base, all records that are found in the search are displayed in a summary display mode. In this mode, four records are displayed on the screen in summary format. Summary format consists of the file number, authors (two lines at most), and the title (two lines at most). The user may display the next page of four lines (or previous), display detailed data on a single record, print the detailed data of all records found in the search, return to the first record found in the search, or quit summary display mode. The top line of the screen displays the name of

the data base, the number of records found in the search, and the number of records remaining to be displayed:

-- Data Base: rdl -- Records Found: 42 -- 38 More --

9. File Number: 85508

Author: Mercer HD

Title: Biological Effects of Electric Fields on
Agricultural Animals

10. File Number: 85509

Author: Ioale P, Guidarini D

Title: Methods for Producing Disturbances in Pigeon
Homing Behavior by Oscillating Magnetic
Fields

11. File Number: 85510

Author: Watkins JP, Auer JA, Morgan SJ, Gay S

Title: Healing of Surgically Created Defects in the
Equine Superficial Digital Flexor Tendon:
Effects of Pulsing....

12. File Number: 85511

Author: ANONYMOUS

Title: Safety of NMR

Enter: Display 9-12), B(ack), F(orw.), T(op), Q(uit),
P(rint), or ? ->

When the display option is entered, the user will enter the number of the record to display, and that record will be displayed with all of its fields. Since the record is usually too large to display on one screen, a single screen full is displayed at one time, with the file number, authors, and title always being displayed. The user can then toggle through the rest of the display, print the current record, or return to summary display mode:

-- Data Base: rdl -- Records Found: 42 -- 38 More --

11. File Number: 85510

Author: Watkins JP, Auer JA, Morgan SJ, Gay S

Title: Healing of Surgically Created Defects in the
Equine Superficial Digital Flexor Tendon:
Effects of Pulsing Electromagnetic Field
Therapy on Collagen-Type Transformation
and Tissue Morphologic Reorganization

=====

Pub. Date: Oct 1985

Auth. Aff.: Dept. Large Animal Med. and Surgery, Col.
Vet. Med., TX A&M Univ., College Station,
TX 77843

Publication: Am. J. Vet. Res., Oct 1985, Vol. 46 No. 10,
p. 2097-2103

Language: English

No. Pages: 7 p

No. Refs.: 43

Field Type: pulsed

Field Char.: 1.5 Hz, pulse duration 90 usec

--More-- <SPACE> or <RETURN> to Continue, Q to Quit:

-- Data Base: rdl -- Records Found: 42 -- 38 More --

11. File Number: 85510

Author: Watkins JP, Auer JA, Morgan SJ, Gay S

Title: Healing of Surgically Created Defects in the
Equine Superficial Digital Flexor Tendon:
Effects of Pulsing Electromagnetic Field
Therapy on Collagen-Type Transformation
and Tissue Morphologic Reorganization

=====

Subject Cat.: healing effects, in-vivo exposure

Subject Mat.: physiology and biochemistry,
cellular and extracellular effects

Issue Areas: tendon injury healing, bone healing

Species: horses, large mammals, livestock, agricultural
animals

Enter P(rint Record, Q(uit), or <RETURN> to re-display:

Conclusion

This is just a brief description of the RDL ELF Library Data Base System. It

does not encompass all of the systems capabilities. The system has been designed, developed, and implemented on RDL's Digital Equipment Corp. VAX 11/780 running the Unix 4.2bsd operating system. This is a multiuser system, which allows the data to be available to several users at once. Overall, the system has provided RDL with an easy and efficient means of creating and maintaining a data base of ELF biological effects literature.

Chapter III

LITERATURE REVIEW, EVALUATION, AND ASSESSMENT

3.1. General Outline

The process of literature review, evaluation and assessment consists of two basic tasks:

1. Literature examination and review.
2. Literature evaluation and assessment.

At the outset, all the relevant citations are examined and their contents are summarized according to the following items:

- o main objective of the article,
- o description of the findings,
- o reported bioeffects (if any),
- o relevance to the ELF Communications System (ELFCS).

The articles relevant to the ELF Communications Program, and containing potentially new significant findings, are further evaluated and assessed. The results are summarized in the Evaluation and Assessment Summary Sheet, where specific items such as description of findings, evaluation and assessment, relevance to the ELFCS, field exposure conditions, and conclusions are addressed for each citation. The following example demonstrates an actual summary sheet used in the process of literature evaluation and assessment.

1. Author : Ottani V, Monti MG, Piccinini G, Pernecco L, Zaniol P, Ruggeri A, Barbiroli B
2. Title : Pulsed Electromagnetic Fields Increase the Rate of Rat Liver Regeneration after Partial Hepatectomy
3. Source : Proc. Society of Experim. Biol. & Med., Vol. 176, pp. 371-377, 1984
4. Description of the Findings : The effects of a pulsed magnetic field on the regeneration of rat livers was studied by combined electron microscopic and biochemical techniques. Rats were partially hepatectomized and then subjected to pulsed magnetic fields for 30 min immediately afterwards and at 12-hr intervals thereafter for periods up to 7 days post-surgery. The field waveform consisted of a major sinusoidal half-wave (50 Hz, 6 mT) followed by 4 cycles of a 400-Hz, 0.6-mT sine wave. Control rats were sham-exposed to the field. The authors reported that the pulsed magnetic field exposure promoted a more rapid regeneration of partially resected livers as compared to the controls. They observed rapid increases in the ornithine decarboxylase levels (an enzyme used as an early marker of cell growth) and in DNA synthesis (based on the incorporation of tritiated thymidine). Glycogen depletion and the accumulation of lipid droplets, both of which occur in partially resected livers, were found to be diminished in the animals exposed to a pulsed magnetic field relative to control rats.
5. Evaluation and Assessment : This study appears to have been carefully performed with proper attention to the use of appropriate sham controls. It demonstrates that a high intensity pulsed magnetic field can favorably influence the rate of liver regeneration following partial hepatectomy. However, it should be noted that the pulsed magnetic field waveform was quite unusual, and has not been used in previous laboratory studies or in clinical trials to determine the effects of pulsed fields on the rate of bone fracture reunion. The authors also made no effort to determine the threshold magnetic field parameters that could influence the rate of liver regeneration.
6. Relevance to ELFCS : The pulsed magnetic field waveform had 50-Hz, 6-mT and 400-Hz, 0.6-mT components. Both of these have substantially larger intensities than the 72- to 80-Hz, 14-uT maximum magnetic fields present in air in the vicinity of an ELF antenna. The results are therefore not directly relevant to ELFCSs.
7. Field Exposure Conditions : Rats were exposed to a pulsed magnetic field produced by a large Helmholtz coil. The pulsed field consisted of a 50-Hz, 6-mT component (1/2 cycle) followed by a 400-Hz, 0.6-mT component (4 cycles).
8. Specific Comments on the Criteria for Scientific Merit : This paper appears to meet the established criteria of scientific merit.
9. Conclusions : The authors have demonstrated by morphological and biochemical criteria that a high-intensity, pulsed magnetic field with an unusual waveform can facilitate liver regeneration in partially hepatectomized rats. The fields used in this research had intensities that were about 50-500 times greater than the sinusoidal magnetic fields present in air near an ELF antenna, and the results are not of direct relevance to the issue of potential biological effects of the fields associated with the ELFCS.

3.2. Technical Consultants

As stated earlier, the main tasks of this program include ELF bioeffects literature search, document retrieval, literature review, evaluation and assessment. consultants. The following expert consultants participated in the literature evaluation and assessment.

Dr. Robert G. Lindberg, Laboratory of Biomedical and
Environmental Sciences, UCLA,
Los Angeles, CA 90024

Dr. Asher R. Sheppard, J.L. Pettis Memorial Veterans Hospital
Loma Linda, CA 92373

Dr. Thomas S. Tenforde, Biology and Medicine Division,
Lawrence Berkeley Laboratory,
Berkeley, CA 94720

Dr. David A. Savitz, Department of Epidemiology,
School of Public Health,
University of North Carolina,
Chapel Hill, NC 27514

All of RDL's technical consultants are well recognized for their research activities in the bioelectromagnetics area and for their active participation in various bioelectromagnetics related events such as symposia, conferences, meetings, etc.

3.3. Literature Characterization and Classification

In order to provide a convenient access to the ELF bioeffects library, the reviewed and evaluated citations are characterized based on exposure field type such as electric, magnetic, geomagnetic, etc., and field category, which is indicative of a particular features of an exposure field, such as frequency, strength, etc. In addition, all documents are classified by subject material, subject category, and issue areas.

The developed subject categories, subject materials, and issue areas are a continuation of those developed by NAS and AIBS. Moreover, these are modified and augmented as appropriate to accommodate scientific development. Clearly, such a thorough classification and characterization of the literature permits one to directly access all data strictly pertinent to a particular and narrow area of interest, avoiding unnecessary time-consuming searches.

3.4. Criteria for Scientific Merit

Since reviewed literature inevitably exhibits considerable quality variation, criteria were established to evaluate scientific merits for each individual citation, and these criteria were used as guides in the process of literature evaluation and assessment. The criteria have not changed since the last final report (November 1986), and they are :

o Definition of the problem investigated:

The objective of a study must be defined clearly and rigorously.

o Definition of environment:

A given experimental or observational report should include all relevant environmental factors such as noise, temperature, vibration, light, electromagnetic fields, and chemical agents.

o Experimental method and protocol:

The experimental techniques used avoid or control factors such as noise, vibration, microshocks and chemicals.

The effective ELF field, voltage, or current applied to the organism should be measured.

The experimental and observational techniques, methods and conditions should be objective. Blind scoring should be used whenever there is a possibility of investigator bias; likewise, data analysis should be objective.

A given experiment should be internally consistent with respect to the effects of interest.

The results should be quantifiable and susceptible to confirmation by other investigators.

A given experiment should be supplemented by a protocol describing experimental setup, duration and level of field exposure, equipment used, and all particular features that could affect the experimental outcome. In addition, protocol should include complete information on object(s) under investigation such as age, sex description of control sham-exposed groups, and other relevant data.

o Sensitivity analysis:

The sensitivity of the experiment should be adequate to ensure a reasonable probability that an effect would be detected if it existed.

When possible, threshold values should be estimated for field intensities and frequencies for which there are noticeable changes in bioeffects.

Maximally sensitive procedures should be employed whenever possible.

o Statistical design and analysis:

Proper statistical techniques should be used to establish the outcome.

o Models employed:

If models are used, it is necessary to assess the degree to which they simulate the geometrical and physical characteristics of the biological object.

Models should be appropriate to the experimental objectives and technique.

o Result interpretation and assessment:

Biological and engineering methodologies should be scientifically sound and appropriate for the experiment(s) or study.

The information reported should be adequate to permit judgements on the conclusions reached.

Data analysis techniques should be clearly described.

The conclusions drawn should not be of a speculative nature or extend beyond the limits of the available data.

These criteria represent a modified and more comprehensive version of the criteria used by AIBS Committee members in 1985 report on biological and human health effects of ELF electromagnetic fields.

3.5. Letter Reports

Seven letter reports were prepared during the period of November 1986- October 1987. The first letter report presented a summary of the Contractors Review Meeting sponsored by the Department of Energy in Denver, Colorado during the period of November 18-20, 1986. The second letter report presented the highlights of the Ninth Annual Meeting of the Bioelectromagnetic Society held in Portland, Oregon, June 21-25, 1987. Both these meetings were attended by RDL representatives.

The next five letter reports present evaluations of new significant findings in the literature pertaining to the controversial issue of a link between magnetic field exposure and cancer. These reports were prepared based on a thorough evaluation and assessment of documents (detailed description of documents follows) by Dr. Asher Sheppard, a recognized expert in the area of bioelectromagnetics. A special report was prepared at the request of the Commander, Space and Naval Warfare Systems Command for presentation at the Second FY 87 Meeting of the ELF Environmental Review Committee, and dealt with the data regarding the effects of Extremely Low Frequency Non-Ionizing Radiation and Cancer in Humans.

LETTER REPORT NO. 1

SUMMARY OF THE CONTRACTORS REVIEW MEETING SPONSORED BY THE DEPARTMENT OF ENERGY IN DENVER, COLORADO, NOVEMBER 18-20, 1986.

BIOLOGICAL EFFECTS FROM ELECTRIC AND MAGNETIC FIELD, AIR IONS AND ION CURRENTS ASSOCIATED WITH HIGH VOLTAGE TRANSMISSION LINES

The objective of this letter report is to highlight the proceedings of the Contractors Review meeting, jointly sponsored by the U.S. Department of Energy and the Electric Power Research Institute which was held at the Sheraton Denver Tech Center, Denver, Colorado, on November 18-20, 1986, under the title "Biological Effects from Electric and Magnetic Fields, Air Ions and Ion Currents Associated with High Voltage Transmission Lines".

The meeting was opened by an introduction to the Department of Energy (DOE) research program by K. Klein, and an introduction to the Electric Power Research Institute (EPRI) program by R. Patterson. The technical sessions for the first day were divided into three symposia: HVdc, HVac and In Vitro Studies.

The first speaker in the HVdc symposium was M. Misakian from the National Bureau of Standards who gave an update of the NBS Electric Fields Project. The objectives of the NBS Electric Fields Project include the evaluation of instrumentation and measurement techniques which are used to characterize the electrical parameters in the vicinity of high voltage transmission lines, and in laboratory apparatus designed to simulate the transmission line environment. Misakian explained that during the past year, a laboratory study on the calibration of aspirator-type ion counters and measurement of unipolar charge density was completed, and work was begun on the measurement of atmospheric ion mobilities using drift tube measurement techniques. The mobility of an ion, K , as it moves through a gas under the influence of a weak electric field is defined as the average ion drift velocity divided by the electric field strength. Measurement of this ion parameter provided useful information regarding ion-molecule reactions in such areas as gaseous electronics and plasma chromatography. Knowledge of the ion mobility, in the high voltage dc transmission line context, permits an experimental determination of charge density, p , using the relation $J = pKE$, where J and E are measured values of the ion current density and electric field strength respectively. In addition, an estimate of the ion mass may be possible under certain conditions. The latter application could be useful for biologists performing bioeffects studies with dc electric fields and ions. In addition, a brief examination was made of using portable radios as means for detecting corona onset in an ac bioeffects exposure system. Sample measurements of ambient ac magnetic fields were made using a recently constructed magnetic field meter, and NBS efforts in the development of an international (IEC) standard and a national (IEEE) standard for the measurement of power frequency electric and magnetic fields were successfully concluded with the approval of the respective documents.

The second presentation was by G.B. Johnson of the General Electric Company on the research program directed to characterize and predict the electrical environment beyond the HVDC transmission line corridor. The objectives were to characterize aerosols by their charge and size, measure the lateral and vertical profiles of the charge density downwind of HVDC lines and to develop a predictive method to calculate the electric field and charge density downwind of HVDC

lines. Measurements of the lateral and vertical profiles of the charge carried by ions and charged aerosols have been made downwind of the HVDC line at HVTRC for both monopolar and bipolar line energisation. Tests were also done with reduced scale model lines to investigate conditions not available with full scale HVDC lines. The charge level drops off quickly with distance from the line. Higher wind speeds produced higher levels of charge density downwind of the DC line within 70m to 100m. For distances greater than 100m, the charge density increases with wind speed up to about 3 meters per second and then decreases slowly with further increases in the wind speed. Johnson reported the development of an instrument capable of measuring the charge size of an aerosol. Measurements of the charge and size distributions of aerosols have been made at various distances downwind of HVDC transmission lines at HVTRC; in a closed room with an ion source, and in ambient conditions at several different locations such as rural western Massachusetts, near the ocean at Cape Cod, and in downtown Newark, New Jersey. All of these measurements except for those done in a closed room with an ion source, have indicated that the predominant charge state is a single charge. Measurements have also indicated that the larger the aerosol, the more likely it is to be multiply charged.

Equations describing the mechanisms (such as charge recombination, turbulent dispersion, ion-aerosol attachment, field transport to ground, and natural ion sources) affecting the downwind field and charge levels have been determined, and are being used to derive mathematical models to predict the level of charged aerosols, ions and electric fields downwind of HVDC transmission lines.

Vernon Chartier of the Bonneville Power Administration presented their work measuring the "Electrical Environment of Pacific NW/SW + 500 KV Intertie". This project has involved collecting dc fields and ion data on a long term continuous basis at the Grizzly Mt. HVDC Test site for almost 2 years. A description of the positions at which the electric field, ion current density, ion density and space charge density are being measured was given. A portable measurement system was built to measure all these parameters at several locations in cattle pens. By comparing the data from the portable site with the data from the fixed site, techniques for predicting dc field and ion exposure for cattle based upon the fixed site data will be developed. The data collected to date has shown that dc fields and ion activity is much higher on the negative side of the line than on the positive side. One of the primary purposes of the electrical measurement program was to characterize the electrical environment off the right-of-way since BPA had already made dc field and ion measurements on the right-of-way on the old test lines at The Dalles using the line geometry that exists on the intertie. Some data on the off the right-of-way was presented. However, at this time it was not clear whether measurements represented charged aerosols or small ions. It was suggested that the cages were probably seeing small air ions as the air was so clean at this test site.

R.J.Raleigh of the Oregon State University presented the findings of the Joint HVDC Agricultural Study. This study is sponsored by the Bonneville Power Administration and eight other utility organizations. Since the uprating of the +400Kv DC Pacific Intertie to +500 KV and a capacity of 2,000 megawatts in January 1985, BPA initiated this study to characterize the electrical environment of the dc line, and secondly to determine the potential effects of this line on agricultural production. The agricultural study being conducted by Oregon State University involves beef cattle, alfalfa and wheat production. The study is on or near the right-of-way of the Celilo-Sylmar dc line, 12 miles southeast of Madras, Oregon. Four pens, about 3.2 acres in size are located between two tower spans directly beneath the line. Similar control pens are located 1,800 feet west and predominantly upwind from the power line. Two-hundred heads of cows with calves were paired and randomly assigned to line or control groups at the initiation of the study. They are fed, bred, managed and handled identically in all aspects. All cows and bulls remain in their respective location during the 3 years of the study. The major study parameters are conception rate, calving interval, weaning weight, and number of calves weaned. Animal

behaviour, herd health and feed intake, factors that may influence production and reproduction, are also measured. Four crop strips 400 ft. x 24 ft., two under each span of the dc line between the cattle pens, and duplicated in the control area, are planted to a 12-ft. wide strip of alfalfa and a 12-ft. wide strip of winter wheat. This permits distance from the line, on either the + or - side, measurements to determine potential effects of the line on crop production. Measurements are yield of grain and forage, seed quality, and growth characteristics. Data presented for the first 2 years (1985 and 1986) of the cattle study and one full year (1986) of the crop study have shown no real positive or adverse effects of the line on the performance parameters measured.

The fifth presentation in the HVdc symposium was by R. Weigle of the Battelle Pacific Northwest Laboratories entitled "Attempts to produce taste-aversion learning in rats exposed to HVdc electric fields". A measure of taste-aversion (TA) learning was used to determine whether exposure to intense HVdc electric fields can produce TA learning in male Long Evans rats. Fifty six rats were distributed into 2 exposure (80kV/m and -80kV/m) and 2 sham-exposure groups (N=14 rats/group). To validate the sensitivity of the test protocol, one of the sham-exposure groups was further subdivided into positive control (25 mg/kg cyclophosphamide injected) and saline control groups (N=7 rats/group). All subjects were placed on a 20 min/day drinking schedule for 12 consecutive days prior to receiving 5 conditioning trials. Each conditioning trial (0.1% sodium saccharin in water given 30 mins prior to 4 hrs of HVdc exposure/sham exposure) was alternated daily with water recovery sessions. Following the last water recovery session a two bottle preference test (between water and saccharin-flavored water) was administered to each group. Results of the positive control group validated the test protocol; saccharin-flavoured water consumed in the two-bottle preference by the cyclophosphamide injected group was 0% compared to 74% for the saline-injected group. Saccharin preference data showed no TA conditioning in the exposed groups when compared to the sham-exposed controls, although there were marginally significant differences in variances among groups across test days. The conclusion was that exposure to intensive HVdc electric fields does not produce TA learning in rats as reflected in their relative consumption of saccharin.

Jeffery A. Creim of Battelle, Pacific Northwest Laboratories was the next speaker. His presentation, "Avoidance of exposure to HVDC electric fields by rats : a dose response study ", was their attempt to determine, using Long Evans rats : 1) if exposure to HVdc electric fields might lead to avoidance behaviour such as that found in the 60 Hz ac electric field research, and 2) if avoidance is found, what role, if any, does the air ion concentration have on this avoidance behaviour. In each experiment, a two compartment, glass shuttlebox was used ; one compartment could be exposed to a combination of HVdc electric fields and air ions while the other compartment remained sham exposed. In each experiment the rats were individually assessed in 1-hr sessions where half the rats (n=20/experiment) had the choice between HVdc electric field exposure and sham exposure, while the other half of the rats received only sham exposure regardless of their location. the exposure levels used were 80, 55, 43, 30, -36, and -55 kV/m, respectively. The air ion concentration was held constant at 1400000 ions/cc (either positive or negative air ions). Rats, having a choice between exposure and non-exposure, relative to sham-exposed animals, significantly reduced the amount of time spent on the exposed side at 80 kV/m ($p < 0.002$) and at both 55 and -55 kV/m ($p < 0.005$), but not at 43, 30, or -36 kV/m. To assess the role of ion concentration in the avoidance behavior observed at field strengths of 55 kV/m or greater, 3 additional experiments were conducted. The HVdc exposure level was held constant at 55 kV/m while the ion concentration was varied between experiments ; 200000, 10000 and <2000 ions/cc. The exposed rats significantly reduced the amount of time spent on the exposed side at 55 kV/m, relative to sham exposed rats regardless of ion concentration (all p 's < 0.005). The conclusions made from these results were that intense HVdc electric fields of 55/-55 kV/m or greater are sufficient to produce avoidance behavior in rats and the ion concentration, whether positive or negative, is not a significant factor in this avoidance behaviour.

The next presentation was by Jonathan M. Charry of the Institute for Basic Research, Stanten Island. The title of the talk was "Dosimetric response of rats to small air ions : importance of relative humidity". The principal focus of the project was to investigate the behavioral activity and the turnover of brain neurotransmitters in two inbred strains of rats exposed to air ions. Secondly, experiments had been conducted to verify the performance of their exposure chambers. Close agreement between the measured ion current and the calculated ion current was observed for the conducting rat model as the ion concentration in the chamber was increased from 30,000 ions/cm³ to 450,000 ions/cm³ at relative humidities of 29%, 50% and 65%. Similar agreement between the measured ion current and the calculated ion current was also observed for rats exposed to the same range of ion concentrations at relative humidities of 50% and 65%. However, at relative humidity of 29%, the ion current collected by the rat was significantly lower than the calculated ion current at ion concentrations greater than 250,000 ions/cm³. In all experiments, a linear relationship was observed between the ion concentration and the collected body current. These results demonstrated close agreement between theoretical and measured values of 'dose' administered to rats by exposure to air ions in the exposure chambers being used at relative humidities above 50%. At a relative humidity of 29%, however, a reduction in the surface conductivity of the fur and skin of the rat resulted in the accumulation of charge on the body surface. This surface charge reduced the collection of ion current by the rat's body. The results of these initial dosimetric studies point out the difficulty in relying on air ion exposure measurements to estimate

The final presentation in the symposium on HVdc was by F.L.Eisele of the Georgia Institute of Technology who reported the identification of ions near HVdc lines. A mobile laboratory containing a high pressure flow opposed drift tube tandem mass spectrometer was used to identify the ions present directly, under and in the vicinity of a HVdc line at Grissly Mountain Research Facility in Oregon. The drift tube section of the apparatus was used to concentrate and extract the ions from the air. The dual collision chamber triple mass spectrometer was then used to 1) fragment ions by low energy multiple collisions (to remove weakly bound clusters) and 2) mass select a core ion to be fragmented using the first quadrupole, and 3) mass analyse the core ion fragments in the third quadrupole. The instrument makes all measurements in real time and has been used previously to identify naturally occurring ions in the lower atmosphere.

The positive ion concentration under the line was observed to be extremely variable, changing by nearly five orders of magnitude. The primary positive ions present both under and near the lines appeared to be a proton plus pyridine or one of several methyl pyridines. The only major positive peak was at mass 80 and has not yet been identified. The major negative ions present under the power lines are NO₃⁻, NO₃-HNO₃, and ions at masses 59, 103, 166 (59 is presently very tentatively identified as an acetate ion with 103 and 166 containing an additional CO₂ and CO₂ plus HNO₃ respectively). At 30 to 60 meters away from the line the only major peaks remaining are NO₃⁻ and NO₃-HNO₃.

All of the major ion peaks seen under the HVdc line except the negative ions at 59, 103, and 166 amu have been seen previously in measurements remote from any HV power lines. The relative concentrations of these ions are, however, believed to be altered by the HVdc lines and the cattle in the test area.

The next symposium dealt with HVac. Mike Silva of Enertech reported their work on AC field exposure assessment. This assessment work focused on the following three areas : Instrumentation, Magnetic field exposure measurements and developing an Exposure assessment computer program. It was reported that a new digital magnetic field exposure measuring device had been developed and demonstrated. The new instrument measures 8" by 4" x 1.5" and weighs about 20 ounces. The device consists of a plastic box that holds a field sensing unit, signal processing and control board, and an on-board computer with 256 Kbytes of CMOS_RAM memory. The sensing

unit (with 6 coils) includes a pair of 200 turn air-core coils and four ferrite core coils with 400 turns each. These coils are used to collect data on magnetic field along the three orthogonal axes of the device. Electronics within the device allows for simultaneous monitoring of induction due to both 60 Hz and rotational movement in the geomagnetic field. Currently, the system is designed to collect data in two optional field ranges : 0-25 mG or 0-250 mG. The on-board computer unit operates on a 9 volt battery and it can be programmed in BASIC using an IBM-PC. The maximum data sampling rate is 100/sec. and it can be controlled by a combination of software and hardware settings. The maximum operational period is usually limited by the quantity of data collected and not battery life. For example, 1 sample every 2 seconds yields about 8 hours of use and one every 8 seconds will last for about 24 hours before memory is full. A software package, DATACALC, has been developed that will perform a number of data analysis and graphics options using the retrieved data. A conductive cloth sash is being developed that can be worn for collecting electric field data.

Magnetic field measurements have been made at 91 domestic sites in six states for a variety of geographic, building age and construction, grounding, distances to lines, locale, etc. across the U.S. Detailed measurements are made on three orthogonal axes at head, chest and belt levels at center of room and other typically occupied room locations. Measurements were also made during use of household appliances. Preliminary data analysis of the room measurements indicates a very skewed distribution of values, weighted at the low-field end of the curve. For all rooms (and all locations in each room), the mean vertical field at head level was 0.745 mG with a S.D. of 1.382 mG and a maximum value of 18.75 mG. Similar orientation appliance use data had a mean of 8.5 mG (S.D. 33.4 mG) and maximum of 500 mG. Comparisons between data at center of room vs other room locations is in progress to determine if field source is typically external or internal to their homes.

The computer program EXPOCALC has been released for use on the IBM-PC. This program provides for exposure modeling by allowing the user to describe temporal and spatial aspects of human activity in a "study area" near a transmission line. Exposure estimates can be tabulated in terms of hours spent in different levels of electric field (magnetic field should be added next year). Enertech Consultants has obtained a commercialization license from EPRI to distribute and support this exposure assessment package.

The HVac symposium continued with a talk by T.S. Tenforde of the Lawrence Berkeley Laboratory on "Portable 60 Hz magnetic field dosimeter with data acquisition capabilities". A portable microprocessor-controlled dosimeter has been developed for monitoring human exposure to power frequency magnetic fields. This compact dosimeter has been designed to measure 60 Hz field intensities that vary from 20 uG to 800 mG, thereby covering the broad range of field levels generally encountered in households and occupational settings.

Field detection is accomplished by three 500-turn coils, which are arranged along orthogonal axes to monitor the x,y, and z components of 60 Hz ambient magnetic fields. Since the coils are also sensitive to electric fields, they are shielded within individual copper chambers. The signal output from each coil is amplified by two 60 Hz bypass preamplifiers in cascade. At field levels of 10 mG or lower, the total maximum gain of the two active filters is set at 10,000 so that a 50 uG field will yield a 3.4 mV signal and a 10 mG field will yield a signal of 680 mV at the output of the second active filter. When the field being monitored exceeds 10 mG, the total gain of the two active filters is automatically decreased to 185. A 20 mG field will thus yield a 22.4 mV signal and a 500 mG field will yield a 580 mV signal at the output of the second active filter.

The second active filter supplies amplified signals to a phase-lock loop (PLL) and synchronous detector. The PLL phase locks with the incoming signal and produces a quadrature voltage-controlled oscillator (VCO) output that is in phase with the incoming signal. The quadrature

VCO output is then used as the demodulating signal for the synchronous detector. The demodulated output is passed through a low-pass filter suppressing all harmonics except the DC component, which is determined only by the amplitude of the incoming 60 Hz magnetic field. The DC output of the synchronous detector is amplified to be compatible with the 0-5 V range of the analog-to-digital converter (ADC) in the data acquisition section of the dosimeter. The amplified detector output and a comparator circuit are used for automatic ranging between the high-gain (10,000) and low-gain (165) signal modes, which are used in the 20 uG-10 mG and 10 mG-600 mG field ranges, respectively.

Three analog switches are used to transfer data to the ADC. Digitisation of the three orthogonal axes is done sequentially. A 12-bit successive approximation ADC is used in the unipolar mode providing 150 uG/bit and 2.5 uG/bit in the low-gain and high-gain modes, respectively. A programmable interface element interfaces the ADC and the universal asynchronous receiver-transmitter (UART) used for serial data transmission to the microprocessor. The UART interfaces the microprocessor with an HP85 computer that is used for initialization and data readout.

Calibration tests for the dosimeter's detection circuit were carried out with a standard coil that provided a known magnetic flux density as a function of the applied current. The coil was placed inside a Mu-metal shield to reduce the background 60 Hz magnetic field to approximately 20 uG. Linearity of the detection system was observed to be within 2% over the range of field intensities from 50 uG to 825 mG. Contamination of the main 60 Hz signal by harmonics was found to be less than 1%. The integrated data acquisition and recording systems of the prototype dosimeter have also been subjected to calibration tests and to field tests in both laboratory and residential environments. In these tests, the dosimeter's performance was found to meet the design specifications.

The final talk in this part of the meeting was by W.T. Kaune of the Pacific Northwest Laboratory and dealt with a "System for the exposure of cell suspensions to ELF electric and magnetic fields". This talk described the developing of an alternate system to the Helmholtz coils to produce electromagnetic fields in which field leakage was greatly reduced. This approach, which is related to that used in the Crawford cell, has the advantage that exposed and control preparations can be physically located close together, for example in the same walk-in incubator. Three 40 cm x 40 cm x 1.3 cm-thick copper plates are placed in a parallel configuration with an interplate spacing of 7.6 cm. A current, I , is directed through the central plate and a current $I/2$ is returned through each of the two outer plates. Up to eight 2.5 cm-diameter cylindrical exposure chambers, located between the plates, can be exposed to uniform magnetic flux densities from 0 to 0.5 mT (0 to 5 G). The magnetic field that control preparations will experience when placed more than 30 cm from the field-generating plates, is reduced by at least 60 dB (ie. a factor of 1000). ELF electric fields from 0 to 50 V/m can be directly generated in the cylindrical exposure chambers by introducing current through graphite electrodes located in their ends.

The third symposium dealt with in vitro studies. "Effects of 60 Hz fields on ornithine decarboxylase activity in bone cells and fibroblasts" was presented by C.D. Cain of the VA Medical Center, Loma Linda. The following is an abstract of the data presented. The agar-bridge system was designed to expose cells in tissue culture to extremely low frequency (ELF) fields in such a manner that fields strengths (0.1-10 mV/cm) and current densities (2.0-200 uA/cm²) are uniform, well defined, and measureable in the tissue culture medium. In addition, the agar-bridge system allows biochemical assays to be done quickly and efficiently. Current is passed in series through growth medium in petri dishes which are connected by glass bridges that are filled with phosphate buffered saline (PBS) and 1% agar. This design allows for uniform field exposure in different petri dishes. The composition of the glass bridge includes two concentric half-circular glass tubes that have different diameters (28 mm and 41 mm) so that 1% agar solution (10 ml) can be poured between the tubes. The tubes are 8 cm long and are sealed at the ends. The resistance of a bridge

is 240 ohms which is comparable to the resistance across a petri dish with medium, 170 ohms. The electric field is generated by a constant current amplifier and Wavetek function generator.

Since ornithine decarboxylase (ODC) activity is an amplified response of signals originating at the cell membrane, its activity in cell culture is an appropriate measure of interaction between electromagnetic fields and biological systems. To record the effects of these interactions, the external event of the cell surface must be amplified to measurable parameters. Since ODC is highly regulated and its activity can be controlled by external signals such as hormones and growth factors, its activity is an excellent marker to monitor membrane signal transduction. In addition, since ODC is absolutely required for cellular growth in all eukaryotic cells, field effects on its activity can be indicative of changes in cell growth and proliferation.

The effects of a 60 Hz field on ODC activity was first tested in primary bone cells. Specifically, the average of 4 experiments showed that a 1-hr exposure to 10 mV/cm field (with an associated current density of 180 uA/cm²) increased ODC activity 2-fold when assayed 15 min to 1 hr after field exposure. At 2-hr and 3-hr post exposure, ODC activity returned to sham-exposed levels. It is important to note that a current density of 180 uA/cm² in the medium is of magnitude similar to the endogenous current densities at the surface of the bone.

In a project that is testing whether 60 Hz electric fields can function as tumor promoters, ODC activity was measured in CH310T 1/2 fibroblasts. ODC is an appropriate enzyme to study in this classical 'in vitro' tumor promotion protocol because ODC activity is affected by known tumor promoters such as the phorbol esters (TPA). In three experiments, a 10 mV/cm field increased basal ODC activity 1.5-2.0 fold for fibroblasts at 50% confluency. The cells were exposed to the field for 1-4 hrs and assayed 15 mins to 3 hrs. after field exposure. This increased ODC activity parallels TPA-stimulated ODC activity in the tumor promotion protocol. These results are consistent with the hypothesis that 60 Hz fields can act as tumor promoters.

"Further studies into the influence of modulated microwave fields on gap junction-mediated resistance to the action of lymphotoxin" was the title of the next talk by William H. Fletcher of the Jerry L. Pettis Memorial Veterans Hospital, Loma Linda. Previous studies from the authors' lab had shown that a 12 hour exposure of Chinese hamster ovary (CHO) cells to a microwave field (450 Mhz sinusoidally modulated at 18 Hz; modulation depth 80%; incident energy 1-1.5 mW/cm²) appeared to mimic the phorbol esters (TPA) in enhancing the action of lymphotoxin (LT) in perturbing gap junctional communications. However the data were flawed due to defective culture chambers that caused the culture medium to become acidic and disrupt gap junctions. The present study has readdressed this question with improved chamber design. CHO and CL1D cells were used along with LA25 cells, a subclone of normal rat kidney (NRK) cells that bears a temperature sensitive gene from Rous Sarcoma virus. At 39 C the viral gene is suppressed and LA25 cells are fully communication competent as are the parental NRK cells. But at 33 C the viral gene expresses and LA25 cells cease to communicate and lose gap junctions. NRK cells are unaffected by the temperature shift. All cells were cultured in 96 well polystyrene plates in 200 ul medium (pH 7.3) at 37 C (CL1D and CHO cells) or 33 C or 39 C (LA25 and NRK cells), using 95% CO₂; 5% O₂ and 100% humidity. Two regimens were used: 1) 2h continuous exposure, or 2) three one hour exposures separated by 2h intervals. For both LT was added after field exposure.

CHO cells exposed for 2h were not affected by LT unless cultures were co-treated with 1.6 uM TPA, in which case cytostasis was double that of cultures exposed to TPA and LT but not the field. In similarly treated CL1D cells neither TPA nor field exposure, alone or together, enhanced the action of LT. LA25 cells were not affected by LT whether it was used at 33 C (no gap junctions) or 39 C (gap junctions present). However, after exposure to the field for three one hour pulses and assay at 33 C cytostasis was enhanced 2-4 fold over that seen in identical preparations carried out at 39 C. Neither the field nor LT had any effect on NRK cells at either temperature.

These data suggest that the modulated microwave field has an enhancing effect on the action of TPA in CHO cells that may be due to a perturbation of gap junctions. On the other hand the LA25 cells appear to be extremely resistant to LT alone but become sensitive to the cytokine after field exposure. However, gap junctions may not be involved in this increased sensitivity because the LA25 cells are unaffected by LT used at 33 C or 39 C. Currently, the possibility that field exposure may increase the number of receptors for LT and it is this mechanism that causes the enhanced cytostasis is being tested.

The third paper entitled "Effects of low energy electromagnetic fields on the transduction of hormonal regulatory signals by bone cell membranes" was presented by Richard Luben of the University of California, Riverside. In their studies on the effects of low energy electromagnetic fields (LEMF - 10 Hz-100 Hz) on the rates of bone turnover, these authors have previously shown that at least one contributing mechanism which promotes the formation of new bone matrix by osteoblasts, is an inhibition by LEMF of membrane-mediated actions of parathyroid hormone (PTH). The present report was based on their current studies designed to further define the molecular processes involved in this perturbation of cell membrane function. The following observations were reported : 1) Monoclonal antibodies can be used to examine the expression of at least six membrane proteins which participate in transduction of PTH regulatory message in osteoblasts. 2) Expression of cell membrane proteins associated with PTH binding is not modulated by LEMF. 3) LEMF decreases the expression of two membrane proteins (80Kd and 20 Kd) which appear to be related to the coupling of PTH receptors to adenylate cyclase. 4) In the absence of added PTH, LEMF increases the efficiency of iodination of membrane proteins in a manner similar to the effects shown in membranes desensitized by prior exposure to PTH. Coupling this with the observations on the effects of LEMF on bone resorption and cAMP kinetics, the authors concluded that treatment of bone cell membranes with LEMF induces a status of the membrane similar to that observed in physiological desensitization, including an altered ionic environment of the membrane, alterations in expression of receptor- cyclase coupling proteins, altered function of nucleotide binding proteins and altered communications between the osteoblast and other cell types. This presentation was concluded with the suggestion that intensive studies need to be pursued to further understand the biological effects of environmental electromagnetic fields on bone metabolism.

The fourth speaker, Craig V. Byus also from the University of California at Riverside spoke about "The effects of Low-energy environmental electromagnetic fields upon the growth related enzyme Ornithine Decarboxylase : Possible relation to tumor promotion". Based on a number of epidemiological studies, exposure to environmental electromagnetic fields has been suggested to be a possible factor in the promotion of malignancy. In an attempt to study the mechanisms, studies from the author's laboratory have implicated the cell membrane as the most likely site of action of EM field-tissue interaction. In the present studies, the authors have investigated the activity of the enzyme ornithine decarboxylase (ODC), the controlling enzyme in the polyamine biosynthetic pathway, which is regulated by a wide variety of growth factors and hormones active at the cell surface. A 1 hour exposure to a 60 Hz EM field of an intensity of 10 mV/cm produced a 5-fold increase in ODC activity in human CEM cells and a 2-3-fold increase in mouse myeloma cells (P3) relative to the unexposed cultures. Depending upon cell type, ODC activity increased during the 1 hour exposure period and remained elevated for several hours after the field exposure ended. In another series of experiments, fields of an intensity as low as 0.1 mV/cm for a 1 hour period produced a 30% increase in the activity of ODC in Reuber H35 hepatoma cells grown in monolayer culture. In the H35 cells, continuous exposure to a 60 Hz EM field (10 mV/cm) for periods of 2 and 3 hours resulted in either no increase in ODC activity (2 hours) or a decrease in enzyme activity (3 hours) compared to the unexposed control cultures. Possible mechanisms of field-cell interaction were discussed.

D.B. Lyle of the Research Services Division of J.L. Pettis Memorial Veterans Hospital, Loma

Linda next gave a presentation entitled "Proliferation of Myeloid Leukemia Cell lines, and allogenic cytotoxicity in the presence of 60 Hz sinusoidal electric fields". Two sets of experiments were reported in which the effects of a 60 Hz sinusoidal electric field on leukomogenesis was evaluated at the cellular level. Measurements of murine cell line M1 cells as measured by a coulter counter in the presence of a tumor promoter TPA and a field of 10 mV/cm (frequency 60 Hz) showed no effect of the electric field on the process. Similarly, negative results were obtained using human myeloid leukemia cell line HL-60. Cell-mediated cytotoxicity was studied by incubating exposed cells with chromium-51 labelled target cells for 4 hours after which time the degree of cytotoxicity was assessed. A 48 hour pre-exposure of the effector cells at 10 mV/cm resulted in a significant 30% inhibition of cytotoxicity, and a 1.0 mV/cm pre-exposure resulted in a significant 18% inhibition, and a 0.1 mV/cm pre-exposure produced a non-significant 7% inhibition. These results suggested a dose-response to the 60 Hz sinusoidal EF with threshold for significant inhibition of cell-mediated cytotoxicity between 0.1 and 1.0 mV/cm.

The last speaker in the Cellular and Molecular section of the symposium on in vitro studies, Marvin E. Frasier of Battelle, Pacific Northwest Laboratories gave a talk entitled "60 Hz electromagnetic fields do not cause strand breaks or cross links in DNA". Both Chinese hamster ovary cells and unstimulated human peripheral lymphocytes were exposed to 60 Hz ac electromagnetic fields (EMF) and their DNA was analysed to determine whether exposure to these fields could directly damage cellular DNA. The cells were exposed to magnetic fields, electric fields and combined electric and magnetic fields. Following exposure, the cells were immediately lysed and analyzed for the presence of induced strand breaks or cross links in their DNA, using alkaline elution techniques. Exposure levels up to 20 Gauss and or 38 V/m were used and no significant DNA damage was found in either EMF exposed or sham-exposed cells. Ionizing radiation was used to show that the cellular system used would provide a dose-related response and nitrogen mustard was used to demonstrate that the assay could detect cross link formation.

In the neurophysiology section of the symposium on in vitro studies, Dr. Asher R. Sheppard of J. L. Pettis Memorial Veterans Hospital, Loma Linda talked about "Exposure of Aplysia burster pacemaker neurons to 60 Hz electric fields alters firing rates and membrane potentials". In this study, identified pacemaker neuron R15 and those of the upper quadrant of the abdominal ganglion of Aplysia californica were studied by intracellular microelectrode recording to determine if in vitro exposure to a 60 Hz electric field affects the burst firing pattern or the membrane potential during the interburst interval (IBI). In vitro exposure periods ranged from 10-20 minutes and electric fields ranged from 0.025 to 10 mV/cm. The observation was that ascending field strengths altered IBIs in 82% of 19 cells exposed to 60 Hz fields. Exposure at 10 mV/cm and two 20 minute periods showed a field related change in IBIs in 50% of the cells tested. The authors concluded that 60 Hz fields in the range of 0.5 to 10 mV/cm modulated the oscillatory cell processes of endogenously active Aplysia neurons. The second day of the meeting was devoted to animal studies, modeling and scaling and human studies. The first speaker, Frederick C. Leung's (Battelle, Pacific Northwest Laboratories) talk was entitled "Effects of electric field or constant light on rat mammary tumor development induced by 7,12-dimethylbenz(a)anthracene (DMBA)". The experiment involved keeping pregnant rats, and the pups born under three different conditions: 1) electric field exposure at 40 mV/m under a 12:12 light/dark regimen; 2) sham exposure with the same lighting schedule and 3) sham exposure under constant lighting. At 54 days of age the pups were administered 7 mg/rat of DMBA via intragastric injection. Rats were subsequently palpated weekly for 18 consecutive weeks to assess the development of mammary tumors. At termination, half the rats from each group were sacrificed at mid-day and the other half at midnight. Serum samples were kept for hormone measurements. At 18 weeks post DMBA injection, there was a significant difference in mammary tumor frequency between rats exposed to constant light and animals exposed to 60 Hz electric fields. There was a suggestion of differences in tumor frequency between rats exposed to an electric field versus sham-exposed and also between rats maintained in constant light versus animals sham-exposed to electric fields. Although the results were

not statistically significant, the author suggested that a definite trend existed for a difference in mammary tumor incidence, induced by DMBA, in rats exposed and sham-exposed to 60 Hz electric fields.

This was followed by Sol M. Michealson of the University of Rochester's School of Medicine and Dentistry on "Neuroendocrine regulation in rats exposed to 60 Hz electric fields". Studies from the author's laboratory using a cannulated rat model which was subjected to 0.4, 0.8 and 1.6 mA footshocks from a Coulbourn grid shocker had shown that the "stress" hormones, corticosterone, prolactin, ACTH and beta endorphin responded to the footshock stimulus in a dose-dependent manner. In the present studies, the authors had used a very sensitive microAmmeter to measure the current induced in the cannulated rat model, and the corresponding hormone responses. The data obtained showed clearly that 80 kV/m field exposure under the conditions used did not elicit a stress response in the rat. The endocrine alterations seen were suggested to be reflections of regulatory adjustments with no pathophysiological implications.

"Effects of 60 Hz electric fields on the daily rhythms of neurotransmitter systems" was the title of the next talk by B.J. Vasquez of Loma Linda University. Results were presented for a study in which male rats were exposed in a parallel rack system to a 36 kV/m, 60 Hz electric field, during 20h/day for 4 weeks. Sham animals were housed in a similar but inactivated system. A 12hour light:12 hour dark lighting schedule was employed. Animals were sacrificed in groups of 6 sham and 6 exposed every 4 hours throughout the day starting at 6.00 a.m. The levels of biogenic amines and their metabolites in the hypothalamus, striatum and hippocampus were determined by HPLC methods. A highly significant interaction between the type of treatment (sham or exposed) and time of day occurred for norepinephrine, dopamine and the serotonin metabolite 5HIAA in the hypothalamus. A sham versus exposed difference was found for the dopamine metabolite DOPAC in the striatum. No circadian or field-related effect was detected in the levels of amines in the hippocampus. Studies were also reported for the binding of opiate antagonist naloxane to brain homogenates. Although there were significant daily rhythms in binding affinities, there were no electric field related effects. The significance of differences in neurotransmitter levels following field exposure are as yet unclear.

The fourth speaker was Larry E. Anderson of Battelle, Pacific Northwest Laboratories who talked about "Morphological aspects of developing cerebellum in 60 Hz electric fields". The purpose of this investigation was to determine the effects, if any, of 60 Hz electric fields on developing rat cerebellum. Pregnant Sprague-Dawley rats were exposed for 20h/day at 100 kV/m field intensity from day one of pregnancy to term, and then the pups along with the mothers for a further 22 days. On sacrifice, the brains were removed and characterized morphologically. The data obtained showed that "the presence or absence of lamellar bodies did not correspond to the presence or absence of exposure to electric fields".

James E. Morris also of Battelle, next reported that attempts in their laboratory to show an effect of 60 Hz electric fields on the immune system had shown no consistent changes in the responses of lymphocytes to either 60 Hz electric or magnetic (0.27-10.9 Gauss) fields.

Larry E. Anderson of Battelle, Pacific Northwest Laboratories next described their protocols which will evaluate whether there is a relationship between electric field strengths and the incidence of malformations in fetuses from female rats exposed to electric fields throughout gestation. Dr. Anderson also reported that they had been testing several bedding materials for their suitability in electric exposure systems, and that their results to date had shown that Antron III provided the best electrical and biological characteristics.

Dr. R. H. Lovely also of Battelle, Pacific Northwest Laboratories described their experiments which attempted to identify the site of action of the food aversion induced by electric fields as

well as the site of action of the electric field aversion. The role of eyes, ears, vibrissae and other body hair in mediating this behaviour was investigated by testing groups of rats with and without eyes, ears, vibrissae and other body hair. It was found that the removal of eyes, ears and vibrissae accounted for significant sources of variance ($p = 0.03, 0.05$ and 0.08 respectively), while the removal of body hair did not. The conclusions thus were that altered facial features were a significant source of variance in the rat's aversion of saccharin-flavored food when placed in an intense 60 Hz electric field.

"Circadian variation in electric field detection" was the title of the next talk, presented by Mark Stell of M.D. Pettis Veterans Administration Hospital. The experiments were to measure the rats threshold for detection of 60 Hz electric fields during different phases of the circadian activity cycle. Two reasons for doing these studies were that 1) in a previous detection study, the authors had found that rats tested later in the day did less well than rats tested in the morning, and 2) Hjeresen and coworkers had reported that both rats and miniature swine spend more time out of the field during their sleeping period than during their active period. The protocol was to train rats to indicate the presence of an electric field by bar pressing in one end of an operant conditioning chamber. The rats used could reliably detect the fields above 4-10 kV/m. Although data analyses at this time was incomplete, the indications were that there was a small or non-existent variation in detection of 60 Hz electric fields during normal circadian activity cycles.

Sander Stern of the University of Rochester School of Medicine and Dentistry talked about "Behavioral effects of 60 Hz electric fields". Studies using two different designs to test for aversive behaviour during exposure to electric fields had shown that under the conditions used, a 100 kV/m field is not an effective aversive stimulus in rats.

The next talk by Dr. Charles F. Ehret of Argonne National Laboratory described "the actions of High strength 60 Hz electric fields on circadian rhythms in small rodents". Previous reports had indicated that in animals entrained to standard 12:12 light-dark conditions, the observed ELF effects were primarily circadian delays with dyschronism and torpor observed less frequently. In the current study, the authors' group had entrained mice and rats to different light-dark cycles before exposure to a 100 kV/m electric field and assessment of responses. For all the entrainment patterns, 50% of the animals subjected to ELF exposure did not show any alterations in their established circadian respiration or activity patterns. The principal circadian responses were phase-advances. Torpor remained essentially unaffected.

Dr. Walter R. Rogers of the Department of Bioengineering, Southwest Research Institute presented an update of their studies on "the effects of 60 Hz electric fields on operant and social stress behaviours of non-human primates". To date, studies using baboons have demonstrated that: 1) the presence of an electric field does not affect operant responding for food rewards; 2) in the absence of food rewards, response contingent termination of electric field exposure will not motivate escape responding, and 3) the presence of an electric field does not affect extinction of the bar pressing response for food rewards. In summary, these results indicated that multiple brief exposures to an electric field, even at 65 kV/m were neither disruptive nor aversive.

Secondly, measurements of detection thresholds had shown that the detection thresholds reported for rats, monkeys and humans are similar. Experiments which involved social groups in electric fields had been done but data were not yet analyzed and hence not presented.

Following lunch, a session was devoted to computer modeling and to human studies. In the first session, Dr. D.L. Lesser of Pacific Northwest Laboratories, described some of the computer codes which have been written for use by the ELF bioelectric effects research community. Some examples of the use of such codes were presented eg. the use of the model to calculate the approximate ratios of external field strengths for man, pig and rat. A target date of December 31, 1986 had

been set for completion of the codes.

The last presentation of the second day was devoted to human studies. Dr. Charles Graham of Midwest Research Institute described their project which will study the effects of 60 Hz electric and magnetic fields on human function. Initial parts of the project had involved the construction of a human exposure facility. This had been followed by a double blind study to evaluate exposure effects on multiple measures of human performance, physiology, biochemistry and subjective state. Effects of the electric fields on some parameters had been observed. In the second phase, additional techniques were developed to measure human brain and cardiac activity during exposure to high voltage fields. Data had been collected on thirty healthy males using these techniques, before, during and after exposure to a 9 kV/m field. Results were awaiting analyses and hence could not be presented.

The day was concluded after a poster and video presentation, and a general discussion on the topics covered during the day.

The third day of the meeting dealt with epidemiologic studies, risk analysis and the regulation of exposure. The first speaker in the epidemiologic symposium was F. Barnes of the University of Colorado. His presentation "On the relationship between wiring configuration and endogenous 60 Hz fields" was a description of their examination of the relationship between the measured fields and the power line types and location (or the wiring configuration). Using the Wertheimer and Leeper code (WL code) for classification of wiring configuration, it was found that the average values for low power endogenous measured fields were in the same rank order as the WL code. Using the Bonneville Power program for small samples of very high field and ordinary high field configuration houses, it was shown that the measured fields could be generated in nearly every case by the distribution lines running at less than half their rated capacity. The authors had also developed a simple approximate model for predicting the magnetic field from the power line geometry and the distance to the house.

"Conclusions drawn from the ELF residential field measurements in the Denver/Boulder epidemiological study" was presented by Howard Wachtel of the University of Colorado. The study had involved measurements of ELF magnetic fields and electric fields in the homes of case and control residents under two conditions: 1) low power usage within the home, and 2) with relatively high (but dispersed) internal power load. The following patterns emerged for the magnetic field data:

1. Good room-to-room correlation--both for high and low power cases.
2. Wide dispersion of magnitudes--similar for high and low power cases.
3. Predominant vertical direction, but large variances for both high and low power.
4. No meaningful statistical correlation between level of high power and field magnitude--although large effects were seen in individual cases.

ELF fields in several houses were also monitored for periods of 24 hours or more, including four homes in which simultaneous records of high wattage were also made. From these limited set of data, the following conclusions were inferred:

1. The variation of magnetic fields is less than twofold throughout the part of the day during which "spot" measurements had been made,
2. Linear frequency response outputs give essentially the same profiles as flat ones.
3. Household power usage profiles are not a good predictor of magnetic field profiles.
4. Magnetic field time profiles appear to generally follow those of distribution line loading,
5. The "spot" measurements made earlier can probably be normalized (for time of day and season) using line loading profiles available from the power companies.

The general conclusion was that the low power magnetic field measurements were the most

meaningful from the standpoint of estimating "long term" ELF exposure conditions in homes.

Dr. David Savitz of the University of North Carolina presented the "Results of case control study of childhood cancer and exposure to electromagnetic fields". Of 357 childhood cases of cancer reported in the Denver area between 1976 and 1983, 253 were interviewed. Age matched controls were identified and interviewed by random digit dialing. The primary measures of exposure were in-home electromagnetic field measurements and wire configuration codes, supplemented by an extensive interview with the parents of cases and controls. Various statistical maneuvers had been carried out to obtain results which suggested an association between electromagnetic field exposure as inferred from wire codes and from measured magnetic fields and cancer in children. However, the authors did acknowledge the limitations of the study eg. the imperfect exposure assessment, incomplete responses of cases and controls and the constitution of the control groups.

Dr. W.T. Kaune of Battelle, Pacific Northwest Laboratories was the next speaker and presented a talk on "Residential ELF magnetic and electric fields measured over 24 hour periods". A magnetic field (B-field) and an electric field (E-field) data acquisition system had been built for characterizing ELF fields in residences in western Washington State. The system has five units : a central data-acquisition and control unit; three probes sensitive to vertical and horizontal B-field components; and one probe sensitive to vertical E-fields. The responses of the probes and associated analog electronics could be set either to be flat in frequency (24 to 1900 Hz) or linear in frequency (13-1700 Hz). Twenty four hour measurements were made in 43 western Washington State residences of the B-field at two points in the family room, the B-field at one point in the bedroom, and the vertical E-field at one point in the family room. In addition, (1) scaled maps were drawn of the distribution wiring within 43 m (140 feet) of these homes and (2) field measurements were made at one point in time by an epidemiological interviewer. The results of this study were :

1. The B-field measured by the two family room probes are weakly correlated.
2. The correlation between the mean 24-hour family room and bedroom B-fields is stronger.
3. Residential 24-h B-fields and E-fields are uncorrelated.
4. Residential B-fields contain substantial harmonic energy, but residential E-fields are nearly pure sinusoids.
5. Residential B-fields exhibit a definite 24-h cycle.
6. The 24-h and "interviewer" B-field measurements are correlated.
7. Residential B-fields are correlated with the wiring code developed by Wertheimer and Leeper; residential E-fields are not.
8. Residential B-fields are not correlated with the distance between a residence and primary or secondary distribution lines.
9. Compared to the Wertheimer-Leeper wiring code, an improved prediction of 24-h average residential B-fields can be obtained using the total number of service drops, the distance to neighbouring transmission lines, and the ampacities of neighbouring primary lines.

The authors could not determine whether these conclusions could be generalized to other geographical areas.

The final presentation in the epidemiologic symposium was Richard Stevens of Battelle, Pacific Northwest Laboratories. The results of a study very similar to one that had previously been described were presented. 164 cases of acute non-lymphocytic leukemia diagnosed between 1981 and 1984 in King, Pierce and Snohomish counties of Washington were identified and matched with 204 controls. Questionnaires were used to record histories. Exposure levels were determined by interviewer point-in-time measurements and actual recordings, and comparisons made. The conclusions that were reached from the available data was that there was no evidence for an association of residential exposure to electric and magnetic fields and risk of acute non-lymphocytic leukemia in the study area and population examined over the years of diagnosis considered.

The meeting then moved into the area of risk analysis. The first speaker was C. Easterly of the

Health and Safety Research Division of the Oakridge National Laboratory speaking about "Data analysis for ELF bioeffects program". The presentation dealt with the statistical approaches that had been identified for the examination of the accumulated results of multiple in vivo experiments. These methods could provide a single test for evidence of a treatment effect, and were valid for experiments that varied in such characteristics as exposure level, duration, laboratory etc. Using this program, if persistent evidence of ELF field effects was to be obtained, then the program would seek to identify effect magnitude and exposure parameters related to a magnitude of effects. Another aspect of the support program that was discussed was the providing of support to the Department of Energy for the evaluation and recommendations for ELF related epidemiologic research. A review of data on available community based disease registries had been completed with regard to possible studies of communities near high voltage transmission lines, and several states where studies could be conducted had been identified.

The final speaker, G. Morgan of the Carnegie-Mellon University talked about the "Risk related studies at Carnegie Mellon". This talk attempted to define "without ambiguity", some of the 50/60 Hz exposures which may be deemed to be hazardous. The presentation also dealt with preliminary results of studies involving small-groups of citizens who were asked to provide advice to the state on a series of hypothetical transmission line siting problems. The pros and cons of the upper limits set by science on possible public health impacts and the cost for risk management were discussed. Morgan finished by stating that after many years of risk assessments, they had recently indicated to the Department of Energy that there was not much more that could be done productively on risk analysis in the area of 50/60 Hz fields until the science of the problem was more complete. As a result it was felt that the Carnegie-Mellon group may not be an active DOE contractor in the near future.

LETTER REPORT NO. 2

SUMMARY OF THE PROCEEDINGS OF THE NINTH ANNUAL MEETING OF THE BIOELECTROMAGNETICS SOCIETY HELD IN PORTLAND, OREGON, JUNE 21-25, 1987

The object of this letter report is to summarize the Proceedings of the Ninth Annual Meeting of The Bioelectromagnetics Society which was held at the Red Lion Inn, Llyod Center in Portland, Oregon during the period of June 21-June 25, 1987. This report has been prepared by Narinder Singh Shargill, PhD., who represented Research & Development Laboratories at this meeting. This letter report will present a brief overview of the meeting , and details of presentations which are relevant to the ELFCS program will be detailed in our monthly progress report.

The meeting was comprised of 13 Scientific sessions consisting of six presentations each with two sessions running concurrently at any one time. There were also mini-symposia and tutorial lectures. There were also two poster sessions. The meeting opened officially on Monday, June 22 with opening remarks by Thomas S Tenforde, the President-Elect of the Society. Dr. Tenforde emphasized the importance of an organization which brought together researchers from a number of disciplines including, Physics, Chemistry, Physiology, Biochemistry and Medicine. The need to interact and produce safety standards in an environment which is increasingly being saturated with various forms of non-ionizing radiation was stressed.

The first symposium was entitled "Magnetic and Electromagnetic Detection Systems : Biogenic Magnetite and other Mechanisms". Four papers were presented dealing with the electromagnetic guidance system in Elasmobranch fish, magnetotactic bacteria, magnetoreception in honeybees and the properties of biogenic magnetite. This was followed by session A under the title " ELF In Vitro Studies" and was chaired by B. Greenebaum and A.F. Sheppard. Dr. S. Lin-Liu and A.R. Sheppard (Loma Linda University and Pettis Memorial Veterans Hospital, Loma Linda, CA) presented their studies on migration of membrane receptor molecules exposed to static and ELF electric fields. Their results showed small but statistically insignificant receptor anisotropy (measured by Concanavalin A binding) in AC but not DC fields. The second paper by A.R. Sheppard et al (Pettis Memorial Veterans Hospital and Loma Linda University, Loma Linda, CA) entitled " Statistical Characteristics of the Activity of 60 Hz Electric Field Exposed Aplysia Pacemaker Neurones" suggested that exposure to 60 Hz electric fields produced changes in the interburst intervals (IBI) in naturally evoked action potentials. However, the changes were sometimes an increase and sometimes a decrease.

J.E. Reese et al (Pacific Northwest Laboratory, Richland, WA) reported that exposure of human lymphocytes to 60 Hz AC emf fields did not produce any significant cross-linking of DNA i.e. damage to the DNA. Stephen F. Cleary et al (Dept. Physiology and Plastic Surgery, Virginia Commonwealth University, Richmond, VA) reported that exposure of chicken tendon explants to a low amplitude, pulsed DC field modulated fibroplasia and collagen synthesis. Increased fibroplasia was induced in explants oriented parallel to applied electric fields with no effects on explants placed perpendicular to the same field. Dr. Greenebaum et al (Biomedical Research Institute, University of Wisconsin-Parkside, WI) showed that there were changes in surface charge of cells exposed to 60 Hz electric and magnetic fields using amoebae. Like previously reported studies, the changes reported were qualitative and methods to quantitate the surface charge changes were discussed. Karl Brinkman et al (University Institutes of Braunschweig and Berlin, West Germany) presented a paper entitled " Effects of Magnetic 50 Hz Fields on Tumor Cells and Peripheral Lymphocytes". The data presented showed no effect of field exposure on Ehrlich-Ascites

and Yoshida-Ascites tumor cells, while there was an increase in growth of human peripheral lymphocytes after 48 and 72 hours exposure. No differences were seen in the SCE (sister-chromatid-exchange) rate of human peripheral lymphocytes.

Session B which was running concurrently with session A was entitled "RF In Vivo Studies" and was chaired by E.R. Adair and M.E. O'Conner. Five papers were presented in this session and dealt with the effect of radiofrequency exposure on monkey eyes, blood-borne hormones in rats, embryogenesis in the Japanese quail and thermoregulation in monkeys.

Session C on "ELF Dosimetry" was chaired by T. Dan Bracken and J. Bowman. Dr. Bowman et al (University of Southern California, Los Angeles, CA) reported on their efforts to conduct some electric and magnetic field measurements in the vicinity of employees from occupation categories assumed to be 'electrical workers' in an attempt to lend credence to epidemiological studies which have suggested an elevated leukemia risk in Richland, WA) reported that a family of computer codes was now available to the bioelectric effects research community for computation of the interaction of biological specimens with ELF electric fields. Some possible applications were discussed.

Drs. R.A. Knight and S. Frinak (Dept. of Neurology, Henry Ford Hospital, Detroit, MI) and Dr. A.R. Liboff (Dept. of Physics, Oakland University, Rochester, MI) reported on their attempts to measure the voltage induced in human subjects due to uniform motion along the axis of a superconducting NMR magnet having the maximum field strength of 1.89 T. From their studies, these authors estimated that the current density corresponding to this exposure was 0.018A/m² at the surface of the heart, a value roughly 50 times smaller than the minimum threshold for ventricular fibrillation in humans.

Dr. Tenforde and colleagues (Lawrence Berkeley Laboratory, University of California, Berkeley, CA) reported on the performance tests of a 60-Hz magnetic field personal dosimeter with data acquisition capabilities. Calibration tests have demonstrated that the dosimeter's detection system is within 2% over the field range of 50 uG to 600 mG. Contamination of the main 60-Hz signal by harmonics was found to be less than 1%. In its present form, the dosimeter meets the original design specifications for both laboratory and residential environment uses. T. Dan Bracken of T. Dan Bracken, Inc. (Portland, OR) and V.L. Chartier (Bonneville Power Administration, Vancouver, WA) reported preliminary data on the measurements of occupational exposure of substation workers to 60-Hz magnetic fields. The session running concurrently with session C was entitled "Pulsed and Modulated Fields" and was chaired by Drs. S. B. Baumann and S.K. Dutta. The first paper presented by Q.P. Lee et al (Dept. of Pharmacology, University of Washington, Seattle, WA) studied the effects of modulated radiofrequency radiation on calcium efflux from chick brains in vitro. The results showed that any changes in calcium efflux could only be correlated with the temperature of the efflux medium. The other papers in this session dealt with effects of radiofrequency radiation on various biological systems.

On the evening of 22 June, the official banquet was held at which time, Dr. Arthur W. Guy was honored with the presentation of the second d'Arsonval Award. Dr. Guy in his acceptance lecture, traced the development of his laboratory's interest in the bioelectromagnetic field with particular regard to effects on biological systems. Of special concern to him was the diminishing funds available for bioelectromagnetics research.

The second day of the meeting, June 23, started with a tutorial on "Dielectric Properties of Cells and Tissues" by Dr. K.R. Foster, and this was followed by a symposium entitled "Magnetic Resonance Imaging And In Vivo Spectroscopy : Current Perspectives" which was moderated by Dr. O.P. Gandhi. Following the symposium, there was a session (session E) on RF Dosimetry-I which was moderated by Drs. S.S. Stuchly and R.J. Spiegel. All six papers presented in this session dealt

with the measurement or calculation of RF energy deposition in various block models of humans. Session F was a Joint Bioelectrochemistry Society/Bioelectrical Repair and Growth Society and the Bioelectromagnetics Society Symposium. Dr. L.A. MacGinitie et al (Dept. of Electrical Engineering and Biology, MIT, Cambridge, MA) presented their studies on the effects of electric fields on protein synthesis in articular cartilage cells in culture. The results showed no serious effect of exposure on protein synthesis. Drs. Ewa Herbst and Carole Bryant (University of Kentucky, Lexington, KY) studied the "Influence of 72-Hz sinusoidal Electromagnetic Field (EMF) on Wound Healing" using rats. They were unable to show any differences in wound healing following exposure to the 72-Hz electromagnetic field. Preliminary data presented by R. Goodman et al (Columbia University Health Sciences, New York, NY) suggested an increase in transcription and translational products in *Drosophila* salivary gland cells after exposure to low-frequency (72 Hz) electromagnetic fields. Dr. C.A.L. Bassett of the Columbia Presbyterian Medical Center, Columbia University, Riverdale, NY) reviewed some studies which showed beneficial effects of low-energy, time-varying ELF magnetic fields in treating therapeutically-resistant condition of the musculoskeletal system. Some possible mechanisms for these effects were mentioned. The last 2 papers in this session dealt with the effect of pulsed magnetic fields on direct calcium activation in relation to mineralisation and the movement of paramecium cilia caused by electric and magnetic fields through modulation of ion binding.

The two afternoon sessions on Tuesday dealt with "RF In Vitro Studies (Session G) and Mechanisms of Interaction (Session H). Among the papers presented in Session H, J.T. Ryaby et al (Mt. Sinai Medical School, New York, NY) proposed that the differentiation of Cloudman melanoma cells seen after EMF exposure was the result of changes in cAMP levels and the cAMP protein kinase activity. Their study showed that upon removal of the em field, cAMP levels and cAMP dependent protein kinase activity increased up to 5 fold and that these changes in activities were the trigger for differentiation of the melanoma cells.

Dr. Liboff et al (Oakland University, Rochester, NY) presented data showing that calcium movement between medium and human lymphocytes in the medium could be modulated by ELF fields in a resonant manner, the so called Cyclotron Resonance. A second presentation by the same group elaborated further on the Cyclotron Resonance of ions as a mechanistic model for emf interactions with biological systems. A. Chiabrera et al (University of Genoa, Italy) reported that low intensity magnetic fields induce a velocity in ligands which then affects their binding processes. The present study had used calcium ions as the ligand. The authors stated that their data were in good agreement with similar data from other laboratories.

The day concluded with a second tutorial lecture by Dr. R. Albanese entitled "The Physics of High Peak-Power of Pulses", and a social event.

The third day, June 24, started with a tutorial lecture "Structural Phase Transitions and Membrane Sensitivity to Electromagnetic Fields" by R.P. Liburdy, and was followed by a workshop and panel discussion "On Cyclotron Resonance Phenomenon in Biology: Theory, Data and Controversy", which was chaired by C. Polk.

Session I was the second session on In Vivo Studies involving Radiofrequency radiation and was chaired by C.G. Liddle and H.Lai. The frequency of radiation involved in these presentations was well in excess of that which is relevant to the ELFCs. The concurrently running session, session J was "ELF In Vivo Studies" and was moderated by W. Rogers and K.R. Groh. The first presentation in this session by C. Graham et al (Midwest Research Institute, Kansas City, MO) was entitled "Further Research on Human Exposure to 60-Hz Fields". In this study, 30 healthy young men participated in a 4 weekly, double blind, exposure test sessions (6- hr/session at 9 kV/m, 0.2G). Numerous physiological and biochemical parameters measured showed no effect of field exposure over controls. There was an increase in the amplitude of the brain's response to non-

target stimuli after exposure and a reduction in the resting heart rate.

In the studies of Groh et al (Argonne National Laboratory, Div. of Biological and Medical Research, Argonne, IL), mice were raised under different photoperiod cycles and exposed to a 100 kV/m electric field for 4 hours. Animals raised in a 16 hr light and 8 hr dark cycle showed a phase advance in the circadian rhythm of activity after exposure to the field. Animals raised under a 8 hr light and 16 hr dark cycle were less sensitive to the electric field exposure. Some animals showed no circadian rhythms after exposure to the electric field, and these animals showed severely dampened waveforms and torpor. W.J. Quinlan et al (University of Rochester School of Medicine, Rochester, NY) investigated neuroendocrine responses in cannulated rats exposed to intermittent or ramped 60-Hz electric fields. These responses were compared with responses in animals which were stressed by foot shock. Measurements of various endocrine factors like ACTH, Corticosterone, Prolactin and beta-endorphin showed no changes between controls and field exposed rats. The authors concluded that field exposure under their conditions did not elicit a stress response in the rat.

The fourth presentation in session J was by John L. Orr et al (Southwest Research Institute, San Antonio, TX). Their studies on operant behavior in non-human primates concluded that exposure to a 30 KV/m electric field had no detectable effect on operant behavior of nonhuman primates. In another study involving nonhuman primates, (also from Southwest Research Institute, San Antonio, TX), it was reported that exposure to a 30 KV/m, 60 Hz electric field had no effect on performance during baseline and post-exposure periods, but during exposure, tension, passive affixed and stereotype behaviors were significantly higher in the electric field exposed groups. The final presentation in this session also from the same group at Southwest Research Institute reported that during electric field exposure, there were very little changes in the postures of baboons although the animals were a little more active than the sham exposed controls.

The afternoon of Wednesday was devoted to poster presentations and site visits to Bonneville Power Administration Facility. the first poster session dealt with Mechanisms of Interaction and the second session dealt with ELF In Vivo Studies. Other topics that were included in the posters were Dosimetry, RF in vivo and In vitro studies, Instrumentation and exposure systems, Standards, Magnetic fields, Modulated and Pulsed fields. Most poster presentations were elaborations of previously presented data. These will be reported in detail in our monthly progress report.

The program on Thursday, June 25 began with a tutorial by F. Carter on "Molecular Electronics". Session K which was moderated by D. L. Conover and A.W. Guy dealt with Radiofrequency dosimetry. Session L was entitled "DC Electric and Magnetic Fields". The first paper by T. Dan Bracken of T. Dan Bracken, Inc (Portland, OR) reported on efforts to quantify exposure levels at the Grissly Mountain Joint HVDC Agricultural Study. The second paper was a description of the project also at the Grissly Mountain HVDC Research facility to conduct an all weather analysis of HVDC fields and ions. The analysis to date indicated that specific effects from wind with unexplained high ion activity of negative polarities. C.T. Gaffey and T. S. Tenforde of Lawrence Berkeley Laboratory (Univ. of California, Berkeley, CA) reported their experiments in which blood flow through the carotid artery was measured during exposure to static magnetic fields The average carotid blood flow rate of 0.14 ml/sec, was not influenced by magnethydrodynamic interactions with magnetic fields of 1.5T. J. A Creim et al (Battelle, Pacific Northwest Laboratories, Richland, WA) presented a paper entitled " Exposure to a 35 KV/m HVDC Electric Field Does not Cause Avoidance Behavior In Rats Within the First 23-hrs of Exposure". The title explains the findings, which were different to those that had previously been obtained with a field strength of 55 KV/m or greater. The next presentation by the same authors also showed negative data with regard to taste-aversion learning in rats exposed to HVDC electric fields. Dr. Andre Bellossi of Laboratoire Biophysique, Faculte de Medecine, France posed the question " Are pulsed magnetic fields more efficient than static magnetic fields ? An observation with AKR mice

" Mice were exposed to a 800 mT static magnetic field, 2 hours a day, 5 days a week until death, a second group was exposed to a pulsed magnetic field (12 or 460 HZ, 30 minutes a day, 2 non-consecutive days a week) and a third group was kept as controls. There was no effect on survival and development of leukemia was the same in both static field exposed and pulsed field exposed mice.

Session M dealt with Medical Applications and Techniques and was chaired by T.W. Athey and C.H.Sutton. Presentations dealt with the use of Magnetic Resonance Imaging, treatment of fractures with ultrasonic modulation and thermoregulation.

The final session, session N was "Cancer Studies", and was chaired by C.V.Byus and H. Wachtel. The first paper by T.E. Aldrich and C.E.Easterly (Oak Ridge National Laboratory, Oak Ridge, TN) criticized epidemiologic studies which had suggested possible risk of cancer with exposure to ELF fields on the basis of design faults. They suggested new strategies for carrying out such studies and thus address this important question. Dr. Wachtel et al (University of Colorado, Boulder, CO) addressed the problems of interpretation of data from the Denver-Boulder ELF Epidemiology study because of the controversy about which of the measurements of exposure, the wiring configuration or point in time measurements were the reliable measure. The third paper by F.C.Leung et al (Pacific Northwest Laboratory, Richland, WA) reported their studies in which rats were either exposed to light or a 60 Hz (40 KV/m) electric field, and injected with a tumor promoter DMBA. There was a higher incidence of tumor formation in rats which had been exposed to the electric field versus rats which had been exposed to a constant light. Serum prolactin concentrations were also elevated in field exposed rats . Also from Pacific Northwest Laboratory, M.E. Frasier and L.E. Anderson reported that an investigation of the in vivo and in vitro assays of immune system components and functions in rats which had been exposed to 60 hz electric fields showed no significant differences between exposed and sham-exposed rats. The assays in this experiment had been verified using Cobolt-60 exposure system.

C.D. Cain et al (Pettis Memorial Veterans Hospital, Loma Linda, CA) reported that 60 Hz electric fields acted as tumor promoters. Their experiments had involved exposure of fibroblasts in culture to 60 Hz fields and measurements of the activity of the enzyme ornithine decarboxylase. There was a 1.5-2.0 fold increase in ornithine decarboxylase activity after field exposure similar to that produced by the tumor promoter TPA. The final presentation by C.V. Byus et al (University of California, Riverside, CA) showed data similar to the previous paper of measurements of ornithine decarboxylase activity and the possible link of electromagnetic fields and tumor promotion.

The meeting ended at 12.30 on June 25, 1987. As indicated, this letter report is a brief overview of the meeting. Presentations that are relevant to the ELFCS and the ELF Program will be reviewed in detail and presented in our monthly progress reports.

LETTER REPORT NO. 3

1. Author: Phillips, J.L., Ruthledge, L., Winters, W.D.
2. Title: Transferrin Binding to Two Human Colon Carcinoma Cell Lines:
Characterization and Effect of 60 Hz Electromagnetic Fields
3. Source: Cancer Research, 46:239-244 (1986)

4. Description of the Findings: The expression of cell surface transferrin receptors was altered by previous exposure to a 60-Hz electric (E+), magnetic (M+) and combined (E+M+) fields in contrast with controls (E-M-). Cultured cancer cells (Colo 205 and Colo 320 DM) were used. Because receptor number depends on cell density, results were presented in relation to predictions based on an inverse relation with cell density. M+ and E+M+ exposures produced maximum receptor expression regardless of cell density, i.e., cell density no longer regulated receptor numbers. Effects of E+ exposure were opposite, producing fewer receptors than expected from the cell density. Three experiments were done at 4, 6 and 8 months following the single 24 hr. exposures and each had similar outcomes in evidence of the permanence of the differences between cell populations. Because transferrin is involved in cell growth after it is internalized into the cytoplasm, these findings are significant in terms of the parallel findings of enhanced cell growth for the M+ and E+M+ groups which appear to have lost regulation of transferrin receptor numbers. The loss of cell density dependent control is evidence for the type of change associated with cancerous transformations, but in as much as these cells are already transformed, the authors suggest the further loss of transferrin receptor regulation "maintains the cell's malignant state".

5. Evaluation and Assessment: The data are evidence in support of the related report of a field effect on colony formation in the same cells. The data presented demonstrate clear changes of about 1.5 to 3 fold in receptor number in the absence of a change in affinity (K_a). The quantitative relation between changes of this magnitude to cell growth changes, and furthermore to colony growth, are not presented and presumably unknown. Thus, it is uncertain if this result adequately explains the colony growth data on a quantitative basis, but it is impressive qualitatively. The long lapse from exposure to testing is of special interest in showing the long-lasting nature of the changes, but also raises questions about possible incidental alterations in the cells over the many generations.

6. Relevance to ELF Communication: These in vitro results are relevant to ELFCS and to possible low level magnetic field influences on human cancer.

7. Field Exposure Conditions: Cell cultures were exposed in upright cylindrical plastic exposure chambers at 37 C to magnetic fields of 1.0 G rms produced by vertical and horizontal Helmholtz coil pairs (circular polarisation), 300 mA/m² rms vertical electric fields (in phase with the horizontal magnetic field if both were applied) produced by agar-embedded stainless steel electrodes.

8. Specific Comments on Criteria for Scientific Merit: The study uses appropriate methodology and obtained clear findings. Statistical tests were not performed. The authors state that variation between duplicate assays was less than 5-10%. In view of the greater magnitude of most differences between treatment groups, the claimed effects appear statistically significant.

9. Conclusions: Prior exposures to 60-Hz electric and magnetic fields affect expression of cell surface receptors which are important in regulation of cell growth. This finding indicates a mechanism for a field influence on cell growth which may be related to the abnormal growth of cancer

cells. The use of cancer cells in this assay does not affect the biological significance of the finding, but it is necessary to be cautious in applying data from an in vitro study with transformed cells to in vivo conditions.

LETTER REPORT NO. 4

1. Author: Phillips, J.L., Winters, W.D., Ruthledge, L.
2. Title: In Vitro Exposure to Electromagnetic Fields:
Changes in Tumor Cell Properties.
3. Source: Intl. Journal of Radiat. Biol., 49(3):463-469 (1986)

4. Description of the Findings: Colony growth and monoclonal antibody binding in two cancer cell lines (Colo 205 and Colo 320 DM) were enhanced by exposure to 60-Hz electric (E+), magnetic (M+) or combined fields (E+M+) as compared with unexposed controls (E-M-). Colony growth was determined 1 week counting colonies which formed in soft agar. Colony formation and monoclonal antibody binding showed statistically significant effects for E+M+ or M+ exposures. In general, effects were strongest for E+M+ and M+ exposures and less for E+ exposures. Cells were chosen for exposure on a randomized basis and experimental conditions of exposure and temperature was held uniformly constant. Cells were cultured for colony forming ability in replicates of six plates at 5×10 or 6.25×10 cells for the Colo 205 and Colo 320 DM cultures respectively. Monoclonal binding studies were performed using antibodies derived from spleen cells exposed to the tumor cells in a separate set of preparations.

Statistically significant results were reported for 9 of 10 experimental runs involving both cultures. Overall averages were not presented, but the relative increases were in the range 0.7 to 6.0, with many of the E+M+ results in the range of 1.5 to 2.0 fold increases. The M+ exposures ranged more broadly and the E+ exposures had relative colony numbers close to 1.0 (including just 4/10 significant findings). The authors note that the field-related changes persisted for several generations after exposure and may show relatively permanent changes in cellular gene expression.

Related papers which discuss the same or related data are Phillips et al. (#86083, 86185), Winters (#86205).

5. Evaluation and Assessment: This experiment provides important information on altered cell growth for 60-Hz exposed cells in culture. The data show reasonable experimental scatter within each run and a relatively wide range of responses among the various runs. The author's take this fact as an indication of the variable nature of the field influence, a reasonable view. Colony formation appears more consistently altered in comparison with the antibody binding test, but there is a low level of internal consistency between the antibody binding effect and strong colony formation effects. There are no glaring inconsistencies, such as an antibody binding effect in runs with no colony growth effects, although the converse, colony effects without antibody effects, did occur frequently. The data suggest a link to the cancer process in that field exposure may enhance growth of cancer cells, but the authors do not make the jump from in vitro results to in vivo effects.

6. Relevance to ELF Communication: These in vitro results are relevant to ELFCS and are of interest in the larger issue of possible low level magnetic field influences on human cancer.

7. Field Exposure Conditions: Cell cultures were exposed in upright cylindrical plastic exposure chambers at 37 C to magnetic fields of 1.0 G rms produced by vertical and horizontal Helmholtz coils pairs (circular polarisation), 300 mA/m² rms vertical electric fields (in phase with the horizontal magnetic field if both were applied) produced by agar-embedded stainless steel electrodes.

8. Specific Comments on Criteria for Scientific Merit: The data and experimental information presented in this paper indicate careful, appropriate methodology. This reviewer is aware of previous criticisms of this work (apparently referring to earlier data with similar exposure and culture conditions) and of a recent attempt (Cohen et al., NYSPLP, 1987) which failed to replicate the colony enhancement effects reported here. Criticisms have correctly emphasized the limitations of work in vitro and challenged the biological significance of changes in colony formation which are generally less than a factor of two. In rebuttal, such small changes could nonetheless be important insofar as they indicate a mechanism for even larger changes which may occur (perhaps infrequently) in vivo. The much weaker evidence from the antibody binding test may indicate the colony growth results involve additional mechanisms, and further work is needed. Finally, because the fields used in this study exceed most levels of environmental exposure to 60-Hz or ELFCS fields, extrapolation to environmental situations is uncertain.

9. Conclusions: This study indicates that magnetic fields and combined electric and magnetic fields at 60-Hz alter cell growth and possibly cell surface antigen expression. The data are of interest for further in vitro evaluations of field influences on cell growth, genome expression and changes in membrane surface properties.

LETTER REPORT NO. 5

1. Author: Phillips , J. L.
2. Title: Transferrin Receptors and Natural Killer Cell Lysis. A Study using Colo 205 Cells Exposed to 60 Hz Electromagnetic Fields
3. Source: Immunology Letters, 13:295-299 (1986)
4. Description of the Findings: The ability of natural killer (NK) lymphocytes to kill Colo 205 cancer cells was reduced by 24 hour exposures to magnetic (M+) or electric and magnetic (E+M+) 60-Hz fields. The extent of cytolysis was inversely proportional to the expression of transferrin receptors on the cell surface. Cytolysis was evaluated with the standard 51 Cr release assay which detects the radioactive chromium released from the lysed cells. Cytolysis (mean +/- SD) of the controls was 36.1 +/- 3.6%, in contrast to 9.1 +/- 2.8% for the E+M+ group and 10.9 +/- 1.4% for the M+ group. Cytolysis among E+ cells was greater than in controls: 55.3 +/- 6.9%. An additional control group of uncloned, unexposed cells had the same results as the cloned, exposed control group. The findings are contrary to an expectation that the transferrin receptors provide a target for binding by the NK cells, but are in the direction to augment survival of cells exposed to M+ or E+M+ field conditions. Hence, for the cells used, cytolysis is not related mechanistically to transferrin receptors, but there is a co-variation in the transferrin receptor expression and reduced cytolysis.
5. Evaluation and Assessment: This study reports reduced cytolysis for cells exposed to magnetic and combined electric and magnetic fields at 60-Hz, whereas electric field exposed cells were more susceptible to the NK cells.
6. Relevance to ELF Communication: These findings are relevant to ELFCS and to issues of cancer in relation to 60 Hz magnetic fields.
7. Field Exposure Conditions: Cell cultures were exposed in upright cylindrical plastic exposure chambers at 37 C to magnetic fields of 1.0 G rms produced by vertical and horizontal Helmholtz coil pairs (circular polarisation), 300 mA/m2 rms vertical electric fields (in phase with the horizontal magnetic field if both were applied) produced by agar-embedded stainless steel electrodes.
8. Specific Comments on Criteria for Scientific Merit: The methodology appears sound, and techniques and results are clearly reported. Statistical tests were not made to assess significance, but in view of the remarkably small variability among 3 to 5 tests (each in triplicate), the findings are clearly significant. The long delay of 5-6 months from exposure to conduct of these tests is noteworthy (see below).
9. Conclusions: The ability of NK cells to lyse target cells was markedly reduced in E+M+ and M+ exposed cells despite increased expression of cell surface receptors for transferrin, which, according to some models for cytolysis, should have had the opposite effect of increasing cytolysis. These in vitro results augment related work from Dr. Phillips which demonstrate changes in colony growth of M+ and E+M+ cells. The long delay (5-6 months) between exposure and conduct of these tests is both possible evidence of a permanent change in exposed cells and potentially an indication of an artifact introduced during the months of continued cell growth. The apparent internal consistency of the data, low variability, and co-variation of M+ and E+M+ data all argue against artifact.

LETTER REPORT NO. 6

1. Author: Goodman, R., J. Abbott and A.S. Henderson.
2. Title: Transcriptional patterns in the X chromosome of *Sciara coprophila* following exposure to magnetic fields.
3. Source: Bioelectromagnetics 8:1-7 (1987).

4. Description of Findings: By means of transcription autoradiography quantitative data were obtained to measure the degree of RNA transcription at the X chromosome of an insect salivary gland. The extent of transcription was measured by counting photographic grains on photomicrographs. Significant changes in transcription of the genetic code were observed following 45 min exposures to either sinusoidal 72-Hz or pulsed magnetic fields (15 or 72 Hz repetition rates) in comparison with unexposed controls. Each type of field produced a different pattern of increased transcription. Effects included both greater transcription at eight portions of the chromosome also active in the controls, and transcription from three loci at which transcription was too low to be detected (or possibly zero) in the controls. The sinusoidal signal and single pulse waveform produced greater degrees of transcription than the pulse train waveform. The quantitative increases in grain counts were large, ranging from about 5 to 10 fold increases in many of the measured loci and averaging about 8 to 10 fold over all the measured regions.

5. Evaluation and Assessment: These quantitative data support the authors' previous reports of increased transcription from magnetic field exposed insect glands. This finding is of great significance as it indicates a means by which these fields couple to essential cellular functions and could have biologically significant effects on cell protein synthesis, regulation and reproduction. The use of an insect gland does not suggest the effect would be limited to lower organisms, but the large size of these chromosomes may be significant to the transduction mechanism. The finding that effects of each waveform were different in degree is important.

6. Relevance to ELF Communication: The sinusoidal waveform used in one part of the study is directly relevant to ELF communications, but the field strength of the sinusoidal signal (1.1 mT peak) exceeds the magnetic field at the antenna site. This study may be of relevance in helping to define a mechanism for magnetic field interactions which may be generally applicable.

7. Field Exposure Conditions: Insect salivary glands were exposed in vitro to a) sinusoidal magnetic fields at 72 Hz (1.1 mT peak); b) a 72-Hz stream of pulses (380 usec positive, 4.5 msec negative, 3.5 mT peak); c) a 15-Hz repetition of a 4 kHz burst of pulses (200 usec positive, 28 usec negative, 1.9 mT).

8. Specific Comments on Criteria for Scientific Merit: This study appears to have been conducted with good techniques and data are clearly presented as photographs and in a table. The experimental techniques appear well controlled and the data presentation suggests a highly significant effect in all cases. There is, however, no indication of the extent of variability among different chromosomes nor were statistical techniques employed in the data analysis. (If large effects occurred with small variability a detailed statistical analysis would be superfluous.) It may be noted that there was evidence presented for the occurrence of loci at which transcription was suppressed.

9. Conclusions: Sinusoidal and pulsed ELF magnetic fields of about 1 mT augment transcription of genetic information with presumed effects on messenger RNA (mRNA) and consequently on protein synthesis.

LETTER REPORT NO. 7

1. Author: Takahashi, K, I. Kaneko, M. Date and E. Fukada.
2. Title: Effect of pulsing electromagnetic fields on DNA synthesis in mammalian cells in culture.
3. Source: *Experientia* 42:185-186, (1985).
4. Description of Findings: DNA synthesis was measured by ³H-thymidine incorporation in Chinese hamster cells (V29) exposed to pulsed magnetic fields of various pulse widths, repetition frequencies and intensities. A significant increase of about 30% in ³H-thymidine incorporation occurred only for a 25 usec pulse width at 100-Hz and a smaller significant effect was found at 10-Hz, 25 usec. Increased thymidine uptake was spread over the range from about 2×10^{-5} T with maximum uptake at 2×10^{-5} T. At higher field strengths the sense of the effect reversed and a 20% decrease was seen at 4×10^{-4} T. No significant changes in ³H-thymidine were found for pulse widths of 8, 50, 75 or 125 usec at 100-Hz.
5. Evaluation and Assessment: The data clearly exhibit significant results ($p < .01$ and $< .001$) only for certain pulse waveform parameters suggesting that cell responses are sharply tuned to the temporal characteristics (width and frequency) but less sharply dependent on field amplitude. These windowed responses are generally consistent with other demonstrations of windowed responses of in vitro studies, although the effective frequencies, pulse widths and amplitudes do not appear to match those of other experiments. The data disagree with a previous study by Liboff et al. (1984) in which effects on DNA synthesis in human fibroblasts were independent of frequency over a wide range which included the range of the present study. These data are a contribution to the literature on windowed biological responses to electromagnetic fields, but they do not themselves illuminate the mechanisms of physical interaction.
6. Relevance to ELF Communication: The field waveforms used in the study are unlike ELF Communications signals, but further understanding of effects such as reported here will be important in eventual determinations of the range of bio-activity by magnetic fields. The field strengths employed include the range of interest in evaluation of ELF Communications near the antenna.
7. Field Exposure Conditions: Cells were exposed in vitro to a pulsed magnetic field (6-125 us, 5-300 Hz and $0.2-4 \times 10^{-4}$) produced by a Helmholtz pair of coils oriented horizontally. Because of the circular petri dishes employed, the induced electric currents in the medium vary with the radial position in the dish. Exposures appear to have been of two days duration.
8. Specific Comments on Criteria for Scientific Merit: The techniques and data are described briefly. They appear to be of good quality and support the author's conclusions. The paper is deficient in omitting the number of dishes from which each data point was derived, cell density during the test (apparently low on the basis of the initial seeding of 104 cells per ml), whether the testing sequence was randomized or ordered, if there were determinations of the magnetic field uniformity over the dish, rise time of the pulsed current (critical to evaluation of the frequency spectrum), the number of dishes tested at once and the precautions taken to assure identical temperatures in the control and test incubators. More complete information on these issues is necessary before the data can be accepted without some doubts on their reliability. The variation in the standard deviations shown on graphs demonstrates acceptable experimental repeatability for a study which appears to use a few dishes per data point. Statistical analysis by t-tests is satisfactory in view of the large differences encountered, but a multivariate analysis is preferable.

9. Conclusions: This paper presents further evidence for temporal and field strength windowing of the response of cell biomolecular synthetic systems to electromagnetic fields in the elf range. The effects on cell growth which are implied by these data may be of significance in in vivo test systems and generally similar waveforms are used to stimulate growth of bone tissue during fracture healing. Pending further details, this paper may provide significant evidence to support the Goodman et al. findings of altered expression of the genome in insect chromosomes exposed to pulsed and sinusoidal magnetic fields. However, it does not support Liboff et.al. who found frequency-independent effects on fibroblasts exposed to sinusoidal magnetic fields.

SPECIAL REPORT

At the request of the Commander, Space and Naval Warfare Systems Command, a special report was prepared for presentation at the Second FY87 Meeting of the ELF Environmental Review Committee, dealing with the data regarding the effects of Extremely Low Frequency Non-Ionizing Radiation and Cancer in humans. A list of citations that had been evaluated by RDL staff and consultants dealing with electromagnetic radiation and cancer in both epidemiological studies and also laboratory studies was prepared for presentation. For each citation, the results were classified as being positive, negative or neutral, as seen by the individual authors. This classification is given in parentheses at the end of each citation. The month and year shown in parentheses at the end of each title represent the respective Monthly Progress Report in which the citation review appears. Overall summaries and conclusions were prepared by RDL consultants.

The following research publications deal with epidemiological data regarding the effects of extremely low frequency nonionizing radiation and cancer in humans :

1. Ahlbom, A., Albert, E.N. et al (1987). Biological Effects of Power Line Fields. New York State Power Lines Project Scientific Advisory Panel Final report. July, 1987 (August 1987)
2. Aldrich, T.E. and Easterly, C.E. (1987). Strategies For Epidemiology Studies of Electromagnetic (EM) Fields. Bioelectromagnetics Society 9th Annual Meeting, June 1987. (August 1987) (Neutral)
3. Anonymous. (1986). Updates : Occupational Health. Microwave News, Vol. 6 (No. 5) : pp 13-14 . (Mar 1987). (+)
4. Barnes, F.S., Wachtel, H. et al (1986). Magnetic Fields and Wiring Configuration. Bioelectromagnetics Society 8th Annual Meeting, June 1986 (Aug 1986). (Neutral)
5. Barnes, F.S. (1986). On the Relationship Between Wiring Configuration and Endogenous 60 Hz Fields. Biological Effects from Electric and Magnetic Field, Air Ions and Ion Currents Associated With High Voltage Transmission Lines. Contractors Review Meeting, Denver, Colorado, Nov. 18-20, 1986. Letter Report (January 1987)
6. Baroncelli, P., Battisti, S. et al (1986). A Health Examination of Railway High Voltage Substation Workers Exposed to Electromagnetic Fields. Amer. J. Int. Med. Vol. 10, No.1, pp 45-56 (September 1986). (-).
7. Bonnell, J.A. (1982). Effects of Electric Fields Near Power Transmission Plant. J. Royal Soc. Med., Vol. 75, pp 933-941 (August 1987). (-).
8. Bonnell, J.A., Broadbent, D.E. et al (1985). Can Induced 50 Hz Body Currents Affect Mental Functions? Intern. Conf. Electric and Magnetic Fields in Medicine and Biology, London, december 4-5, 1985. pp 117-121 (August 1987). (-).
9. Bonnell, J.A. (1986). Research on Biological Effects of Power Frequency Fields. Int. Conf. Large Voltage Electric Systems, August 27-September 4, 1986, Paris, France. (August 1987). (-).
10. Bowman, J.D., Peters J.M. et al (1987). Design For A Case-Control Study of Childhood

Leukemia and ELF Electromagnetic Fields. Bioelectromagnetics Society 9th Annual Meeting, June 1987.(September 1987) (Neutral)

11. Bowman, D., Garabrant, H. et al (1987). Occupational Exposure to ELF Electric and Magnetic Fields. Bioelectromagnetics Society 9th Annual Meeting, June 1987. (July 1987) (Neutral).

12. Broadbent, D.E., and Broadbent, M.H.P. (1985). Health of Workers Exposed to Electric Fields. British J. Indust. Med. No. 42 : pp 75-84. (November 1986 Final report) (-)

13. Calle, E.E. and Savitz, D.A. (1985). Leukemia in Occupational Groups with Presumed Exposure to Electrical and Magnetic Fields. New Eng. J. Med. Vol 213(No.23) : pp 1467-1477 (November 1986 Final report). (+)

14. Coleman, M , Bell, C.M.J. et al (1985). Leukemia and Electromagnetic Fields : A Case Control Study. International Conference on Electric and Magnetic Fields in Medicine and Biology (Conf. Publ. # 257) : pp 122-125 (Mar 1987).(+).

15. Crocetti, A.M. (1983). Report on Conferences with Dr. Nancy Wertheimer, and Wertheimer Response. New York Dept. of Health Power Lines Project. February 1983. (November 1986 Final Report). (+)

16. Dan Bracken, T. (1987). Measurements of Occupational exposure to Substation Workers to 60-Hz Magnetic Fields. Bioelectromagnetics Society 9th Annual Meeting, June 1987. (July 1987) (Neutral)

17. Flodin, U., Fredriksson, M. (1986). Background Radiation, Electrical Work, and some other Exposures Associated with Acute Myeloid Leukemia in a Case Reference Study. Arch. Environ. Health. Vol.41 : pp 77-78 (November 1986 Final Report).(+).

18. Gilman, P.A., Ames, R.G. et al (1985). Leukemia Risks Among U.S. White Male Coal Miners : A Case-control Study. J. Occup. Med. Vol.27 (No. 9) : pp 669-671. (Nov 1986; Mar 1987). (+)

19. Lin, R.S., Dischinger, P.C. et al (1985). Occupational Exposure to Electromagnetic Fields and the Occurrence of Brain Tumors. An Analysis of Possible Association. J. Occup. Med. Vol.27 (No. 6) : pp 413-419 (November 1986 Final Report). (+)

20. Marino, A.A., and Morris, D.M. (1985). Chronic Electromagnetic Stressors in the Environment : A Risk Factor in Human Cancer. J. Environ. Sci. Health. Vol C3 (No. 2) : pp 189-219. (Nov 1986). (Neutral)

21. McDowall, M.E. (1986). Mortality of Persons Resident in the Vicinity of Electricity Transmission Facilities. British J. Cancer, No.53 :pp 271-279 (November 1986 Final Report)(+)

22. Milham, S. (1985). Silent Keyes : Leukemia Mortality in Amateur Radio Operators (letter to the editor). The Lancet, April 1985 :pp 812. (November 1986 Final Report). (+)

23. Milham Jr., S. (1985). Mortality in Workers Exposed to Electromagnetic Fields. Environ. Health Perspectives. Vol. 62 : pp 297-300. (Apr 1987). (+).

24. Myers, A., Cartwright, R.A. et al (1985). Overhead Power Lines and Childhood Cancer. International Conference on Electric and Magnetic Fields in Medicine and Biology (Conf. Publ. # 257) : pp 120-130. (Mar 1987) (+)

25. Olin, R., Vagero, D. et al (1985). Mortality Experience of Electrical Engineers. British J. Indust. Med. Vol42 (no. 3) : pp 211-212 (November 1986 Final Report). (+)
26. Pearce, N.E., Sheppard, A.R. et al. (1985). Leukemia in Electrical Workers in New Zealand (letter to the editor). The Lancet, April 1985 (November 1986 Final Report). (+)
27. Savitz, D.A. (1986). Case-Control Study of Childhood Cancer and Residential Exposure to Electromagnetic Fields . Bioelectromagnetics Society 8th Annual Meeting, June 1986. (Aug 1986) (-)
28. Savitz, D.A. and Calle, E.E. (1987). Leukemia and Occupational Exposure to Electromagnetic Fields : Review of Epidemiologic Surveys. J. Occup. Med. Vol. 29 : pp 47-51. (August 1987) (+)
29. Savitz, D.A. (1986). Results of a Case Control Study of Childhood Cancer and Exposure to Electromagnetic Fields. Biological Effects from Electric and Magnetic Field, Air Ions and Ion Currents Associated with High Voltage Transmission Lines. Contractors Review Meeting, Denver, Colorado, Nov. 18-20, 1986. Letter Report (January 1987).
30. Sheikh, K. (1986). Exposure to Electromagnetic Fields and the Risk of Leukemia. Arch. Environmental Health, Vol. 41, pp 56-63. (August 1986) (-).
31. Spitz, M.R. and Johnson, C.C. (1985). Neuroblastoma and Paternal Occupation (A Case-control Analysis). Amer. J. Epidem. Vol. 121 (No. 6) : pp 924-929. (November 1986 Final Report). (+)
32. Stern, F.B., Warweiler, R.A. et al (1986). A Case-control Study of Leukemia at a Naval Nuclear Shipyard. Amer. J. Epidem. Vol.123 (No. 6) : pp 980-982 . (November 1986 Final Report). (+)
33. Stevens, R.G., Severson, R.K. et al (1986). Epidemiological Study of Residential Exposure to ELF Electric and Magnetic Fields and Risk of Acute Non-Lymphocytic Leukemia. Biological Effects from Electric and Magnetic Field, Air Ions and Ion Currents Associated with High Voltage Transmission Lines. Contractors Review Meeting, Denver, Colorado, Nov. 18-20, 1986. Letter Report (January 1987).
34. Tomenius, L. (1985). 50-Hz Electromagnetic Environment and the Incidence of Childhood Cancer in Stockholm County. Bioelectromagnetics, Vol. 7 : pp 191-207. (Dec 1986). (Neutral)
35. Tornqvist, S., Norell, S. et al (1986). Cancer in the Electric Power Industry. British J. Indust. Med. Vol.43 : pp 212-213. (November 1986 Final Report).(+)
36. Wachtel, H. and Barnes, F. (1987). Two Alternative Interpretations of the Denver-Boulder ELF Epidemiology Study. Bioelectromagnetics Society 9th Annual Meeting, June 1987. (August 1987) (Neutral)
37. Wachtel, H., Barnes, F. et al (1986). The Predominant Statistical Influence of Outside Sources in Producing Non-Appliance ELF Fields in Homes. Bioelectromagnetics Society 8th Annual Meeting, June 1986 (Aug 1986). (Neutral)
38. Wachtel, H. (1986). Conclusions Drawn from the ELF Residential Field Measurements in the Denver-Boulder Epidemiological Study. Biological Effects From Electric and Magnetic Field, Air Ions and Ion Currents Associated with High Voltage Transmission Lines. Contractors Review

Meeting, Denver, Colorado, Nov. 18-20, 1986. Letter Report (January 1987).

39. Zaret, M.H. (1986). Radiofrequency Irradiation As A Factor in Human Tumors, Teratism and Cancer : The Resonance Frequency Hypothesis. J. Bioelectricity, Vol. 5 (No. 1) : pp 47-53. (Jun 1987).(Neutral)
40. Burch, J.D., Craib, K.J. et al (1987). An Ex-Case Control Study of Brain Tumors in Adults. JNCI., pp 801-809 (August 1987) (-).
41. Coggon, D., Pannett, B. et al (1986). A Survey of Cancer And Occupation in Young and Middle Aged Men. II. Non-respiratory Cancers. Brit. J. Indust. Med., Vol. 43, pp 381-386 (August 1987) (+).
42. Gallagher, R.P., Elwood, J.M. et al (1985). Risk Factors for Occular Melanoma : Western Canada Melanoma Study. JNCI., Vol. 74, pp 775-778 (August 1987) (-).
43. Male, J. C., Norris, W.T. et al. (1985). Alternating Electric and Magnetic Fields Near Electric Power Equipment : Are They a Health Hazard ? J. Soc. Rad. Protection., Vol. 5, pp 179-185 (August 1987). (-).
44. McLaughlin, J.K. et al (1987). Occupational Risk For Intracranial Gliomas in Sweden. JNCI., Vol. 78, pp 253-257 (August 1987). (-)
45. Stevens, R.G. (1986). Epidemiological Studies of Cancer and Residential Exposure to Electromagnetic Fields. Power Lines Project.(Final report, November 1986). (-)
46. Thomas, T.L.(1987). Brain Tumors and Occupational Risk Factors. Scand. J. Work Environmental Health. A Review. (August 1987) (+).

The results of these studies can be summarized as follows (Dr. David Savitz):

There has been an increasing amount of literature pertinent to the possible effect of electromagnetic fields on cancer risk during the past year. In spite of claims of Winters and Phillips, it seems that there is still little empirical biological basis for low-level magnetic fields increasing the risk of cancer. Nonetheless, there are reasonable hypotheses about effects on cell membranes that could promote human cancers. It should also be noted that there are no well conceived studies demonstrating that cancer promotion does not occur.

The changes to the epidemiologic literature are dominated by two New York State Power Lines Project cancer studies, along with additional anecdotal evidence regarding occupational risks. The residential studies show no effect on adult non-lymphocytic leukemias but do suggest an effect on childhood cancer. These studies improved upon past literature in several respects so that the negative and positive findings, respectively, warrant follow-up studies. The occupational literature includes further reports of the presence or absence of association by job title, but no studies with improved methodologies.

In balance, the direction of the literature is in the direction of increased epidemiologic support for an effect of prolonged magnetic field exposure on cancer risk (though short of convincing evidence). The laboratory evidence does not

provide a mechanistic basis for such observations, making the interpretation of the overall literature inconclusive.

Of the 46 citations evaluated, nineteen (19) reported positive effects, Twenty-two (22) negative effects and fifteen (15) were neutral as viewed by the authors.

The following is a list of publications which deal with laboratory studies investigating the effect of electric and magnetic fields on carcinogenesis.

1. Adey, W.R. (1987). Cell Membranes, Electromagnetic Fields and Cancer Promotion. Bioelectromagnetics Society 9th Annual Meeting, June 1987. (August 1987) (+)
2. Ahlbom, A. Albert, E.N. et al (1987). Biological Effects of Power Line Fields. New York State Power Lines Project Scientific Advisory Panel Final Report, July 1987 (August 1987).
3. Brinkman, K., Sander, R. et al (1987). Effects of Magnetic 50-Hz Fields on Tumor Cells and Peripheral Lymphocytes. Bioelectromagnetics Society 9th Annual Meeting, June 1987.(July 1987) (Neutral) *
4. Byus, C. V., Pieper, S.F. et al (1987). The Effects of Low-Energy 60-Hz Environmental Electromagnetic Fields Upon the Growth-Related Enzyme Ornithine Decarboxylase. Possible Relation to Tumor Promotion. Bioelectromagnetics Society 9th Annual Meeting, June 1987.(August 1987) (+)
5. Cain, C.D., Malto, M.C. et al (1987). Effects of 60 Hz Fields on Ornithine Decarboxylase Activity in Bone Cells and Fibroblasts. Bioelectromagnetics Society 9th Annual Meeting, June 1987.(August 1987) (+)
6. Carsten, A. L. and Benz, R.D. (1986). Effects of 60-Hz, 50 KV/m - 10 Gauss Electromagnetic Fields on Dominant Lethal Mutations, Multigeneration Prosperity and Bone Marrow Sister Chromatid Exchanges and Cell Cycle Time in Two Strains of Mice. Bioelectromagnetics Society 8th Annual Meeting, June 1986. (Jan 1987) (-)
7. Carsten, A.L., Benz, R.D. et al (1987). Mutagenicity and Toxicity of 60- Hz Magnetic and Electric Fields. Biological Effects of Power Line Fields. New York State Power Lines Project Scientific Advisory Panel Final report. July, 1987. (August 1987).
8. Cohen, M.M., Kunska, J. A. et al. (1986). Effect of Low Level, 60-Hz Electromagnetic Fields on Human Lymphoid Cells. I. Mitotic rate and Chromosome Breakage in Human Peripheral Lymphocytes. Bioelectromagnetics, Vol. 7 : pp. 415-423(August 1987) (-) *
9. Cohen, M.M., Kunska, J.A. et al (1986). The Effect of Low-Level 60-Hz Electromagnetic Fields on Human Lymphoid Cells. II. Sister-Chromatid- Exchanges in Peripheral Lymphocytes and Lymphoblastoid Cell Lines. Mutation Research, Vol. 172 : pp. 177-184.(June 1987) (-) *
10. Croce, C.M. (1986). Chromosome Translocation And Human Cancer and Leukemia. Cancer Research, Vol. 46 : pp. 6019-6023.(August 1987) (-) *

11. d'Ambrosia, G., Scaglione, et al (1985). Chromosomal Aberrations Induced by ELF Electric Fields. *J. Bioelectricity*, Vol. 4 (No. 1) : pp 279- 284.(January 1986)
12. Dorr, R.T., Soble, M.J. et al (1986). Pulsed Electromagnetic Fields Do Not Reduce Vesicant Skin Ulcers in Mice. *J. Bioelectricity*, Vol. 5 (No. 1) : pp 13-24 (Jun 1987) (-)
13. Goodman, R., Abbott, J. et al (1987). Transcriptional Patterns in the X-Chromosome of *Sciara Corophila* Following Exposure to Magnetic Fields. *Bioelectromagnetics*, Vol. 8, pp 1-7. Letter report (February 1987). (+).
14. Leung, F.C., Rommereim, D.N. et al (1987). Effects of Electric Field on Rat Mammary Tumor Development Induced by 7,12-Dimethylbenz(A)anthracene (DMBA). *Bioelectromagnetics Society 9th Annual Meeting*, June 1987 (August 1987) (-)
15. Lyle, D.G., Kamin, G.W. et al (1985). T-cell growth factor Production and 3H-Thymidine Incorporation by the Myeloid Leukemia Cells M1 and U937 in the Presence of 12-O-Tetradecanoyl-phorbol-13-Acetate (TPA) are Unaffected by 60-Hz Pulsed 20 Gauss Magnetic Field. *Bioelectromagnetic Society 7th Annual Meeting*, June 1985. (November 1986 Final Report) (-)
16. Lyle, D.G. (1986). Proliferation of Myeloid Leukemia Cell Lines and Allogenic Cytotoxicity in the Presence of 60-Hz Sinusoidal Electric Fields. *Biological Effects from Electric and Magnetic Field, Air Ions and Ion Currents Associated With High Voltage Transmission Lines. Contractors review Meeting*, Denver, Colorado, Nov. 18-20, 1986. Letter Report (January 1987). (-)
17. Nordenson, I., Hansson-Mild, K. et al (1984). Clastogenic Effects In Human Lymphocytes of Power Frequency Electric Fields : In Vivo and In Vitro Studies. *Radiation and Environ. Biophys.* Vol. 23 (No. 3) : pp 191-201. (November 1986 Final Report). (+) *
18. Phillips, J.L., Winters, W.D. et al (1986). In Vitro Exposure To Electromagnetic Fields : Changes in Tumor Cell Properties. *Int. J. Radiat. Biol.* Vol. 49 (No. 3) : pp 463-469. (Jun 1987) (+)
19. Phillips, J.L., Ruthledge, L. et al (1986). Transferrin Binding to Two Human Colon Carcinoma Cell Lines : Characterisation and Effect of 60-Hz Electromagnetic Fields. *Cancer Res.* , Vol. 46, pp 239-244. (September 1987).
20. Takahashi, K., Kaneko, M. et al (1986). Effects of Pulsating Electromagnetic Fields on DNA Synthesis in Mammalian Cells in Culture. *Experientia*, Vol. 42 : pp 185-186. (Mar 1987) (Neutral)
21. Winters W D. (1986). Biological Functions of Immunologically Reactive Human and Canine Cells Influenced by in vitro Exposure to 60 Hz Electric and Magnetic Fields. Contractor's Final Report. New York State Power Lines Project. Contract # 218207.(August 1987) (-).
22. Bens, R.D. and Carsten, A.L. (1986). Effects on Dominant Lethal Mutations, Multigeneration Prosperity and Bone Marrow Sister Chromatid exchange and Cell Cycle Time by 60-Hz, 50 kV/m - 10 Gauss Electric/Magnetic Fields in Two strains of Mice. *Bioelectromagnetics Society 8th Annual Meeting*, June 1986. Letter report (July 1986). (-).
23. Cadossi, R. et al (1986). Effect of ELF Electromagnetic Fields on Lectin Induced Lymphocyte Proliferation. *Bioelectromagnetics Society 8th Annual Meeting*, June 1986. Letter report (July 1986). (+).

24. Maffeo, S. et al (1986). Lack of Effect of Weak Low Frequency Electromagnetic F fields on Chick Embryogenesis. *J. Anat.*, Vol. 139 (4), pp 613-618. Final report (November 1986). (-).

25. Sisken, B.F. et al (1986). Pulsed Electromagnetic Fields and Normal Chick Development. *J. Bioelectricity*, Vol. 45, pp 25-34. (June 1987). (-).

Of the total of 25 citations dealing with laboratory studies on the effect of nonionizing radiation and cancer studies in the laboratory, seven (7) were positive, twelve (12) were negative and six (6) were neutral as viewed by the respective authors.

A review of these studies is summarized as follows (Dr. Asher Sheppard):

Significant additional new information from in vitro studies in cell systems includes positive evidence for effects on the transcription and translation processes (Goodman, Abbott and Henderson, 1987) evidence for frequency and amplitude effects on protein synthesis (McLeod, Lee and Ehrlich, 1987), and for changes in the rate of DNA synthesis in cultured fibroblasts (Takahashi et al., 1985). The significance of these studies with sinusoidal electric or magnetic fields (over a range of field strengths) follows from with the central role these processes have in all cell functions. For this reason, it is appropriate to speculate that weak ELF fields may affect any of the manifold of cell functions. These include cell development (in normal growth or the cancer process), may lead to the defective embryo development suspected from studies of chicks in pulsed magnetic fields or relate to altered CNS functions including circadian rhythm disturbances. Of course it is necessary to follow-up on such speculations with specific hypotheses and experiments.

Additional evidence of in vitro cellular responses includes a controversial finding of field-stimulated changes in colony forming ability of a line of cancer cells and in changes in membrane receptors and in cell vulnerability to cytotoxic lymphocytes (Winters et al., 1986; Phillips, 1986; etc.) An outstanding aspect of these reports is the fact that the changes introduced by a relatively brief 24 hr exposure were demonstrable up to 8 months later, indicating heritable, permanent changes. An attempt to replicate the field influence on colony formation in another laboratory was unsuccessful (Cohen et al., 1987). This area requires additional investigation.

Research with pulsed magnetic fields indicates changes in receptor-mediated events at the membrane surface (Cadossi et al., 1986) and augment previous reports such as those from Luben (1982). There is also new information on changes in intracellular enzymes in field-exposed cells.

On the other hand, during this same time period there have also been a number of significant studies with negative results which indicate the absence of significant effects on chromosomes or embryo development following in vivo exposures (Benz et al., 1986, Cohen et al., 1986) Both Maffeo et al. (1984) and Sisken et al. (1986) were unable to replicate an effect of pulsed magnetic fields on chick

embryo development, but Juutalinen (1986) was able to repeat the previous work, although with somewhat different thresholds.

In summary, there has been rapid development in a number of scientific areas relevant to ELFCS. There is still a very unclear picture of the public health implications of exposures to weak ELF fields, but the most recent trends emphasize caution concerning chronic exposure to ELF fields although acceptable thresholds have not yet been established.

The following tables summarize important findings from a number of studies concerned with exposure to power-frequency electromagnetic fields and cancer risk :

TABLE 1

RESIDENTIAL EXPOSURE TO POWER-FREQUENCY
ELECTROMAGNETIC FIELDS AND CANCER RISK

Authors	Geographic Location of Study	Cancer Type	Relative Risk	Significance
Childhood Cancer				
Wertheimer & Leeper, 1979	Colorado	All Cancers	1.6-1.9	Yes
Fulton et al., 1986	Rhode Island	Leukemias	1.0-1.2	No
Tomenius, 1986	Stockholm County	All Cancers	1.2-1.9	Yes
Savitz et al., 1987	Colorado	All Cancers	0.9-2.0	Yes/No
Adult Cancer				
Wertheimer & Leeper, 1982	Colorado	All Cancers	1.2-2.2	Yes
McDowall, 1986	United Kingdom	All Cancers	0.9-1.2	No
Stevens et al., 1987	Washington State	Acute Nonlympho- cytic Leukemia	0.8-1.4	No

COMMENTS ON TABLE 1

Summary of residential studies on cancer risk in relationship to power-frequency field exposure. Relative risk of cancer was estimated from data in cited publications, and includes the range for various high-current configurations (HCC) of power distribution lines near the households. The only strongly positive results were the two Wertheimer & Leeper (W/L) studies in Colorado and the Tomenius study in Stockholm. The W/L studies are generally dismissed by reputable epidemiologists as being seriously flawed due to non-blind encoding procedures and resultant investigator bias. The Tomenius study may suffer from a similar problem, although he claimed in his paper that the estimation of magnetic field levels in residences was done by a "blind" technique. The Savitz study is perplexing because the correlation of cancer risk and the presence of HCC power lines was positive, but the magnetic fields measured in the residences were not correlated with cancer risk. Overall, the data suggest that no relationship exists between power-frequency field exposure in the household environment and cancer risk. There is a need for one, or possibly two, additional epidemiological studies that carry out proper dosimetry to estimate magnetic variables such as smoking habit, etc.

TABLE 2

RELATIVE RISK (RR) ESTIMATES FOR TOTAL
LEUKEMIAS, ACUTE LEUKEMIAS AND ACUTE
MYELOGENOUS LEUKEMIAS*

[SUMMARY OF ELEVEN PUBLISHED DATA SETS]

Electrical Occupations	Total Leukemias RR (95% C.I.)	Acute Leukemias RR (95% C.I.)	Acute Myelogenous Leukemias RR (95% C.I.)
Electrical equipment assemblers	2.4 (1.0-4.8)	-	-
Aluminum workers	1.9 (1.2-2.9)	2.6 (1.3-4.6)	-
Telegraph, radio and radar operator	1.8 (1.4-2.6)	2.1 (1.3-3.3)	2.6 (1.4-4.4)
Streetcar, subway and railway motormen	1.7 (0.7-3.3)	-	-
Power station operators	1.6 (0.8-3.0)	2.2 (0.6-5.7)	-
Electronic technicians	1.3 (0.9-1.8)	1.8 (1.0-3.0)	1.9 (0.8-3.8)
Power and telephone linemen	1.3 (1.0-1.6)	1.7 (1.1-2.5)	2.5 (1.1-4.9)
Electrical and electronic engineers	1.2 (1.0-1.5)	1.8 (1.2-2.3)	1.9 (1.3-2.7)
Electricians	1.1 (0.9-1.2)	1.1 (0.9-1.4)	1.0 (0.7-1.5)
Motion pictures projectionists	1.1 (0.5-2.2)	1.2 (0.1-4.5)	-
Telephone repairers and installers	0.9 (0.6-1.3)	1.1 (0.6-1.8)	1.0 (0.4-1.8)
Welders and flame cutters	0.9 (0.7-1.2)	1.0 (0.7-1.5)	1.7 (0.5-4.5)
TOTAL	1.2 (1.1-1.3)	1.4 (1.2-1.6)	1.5 (1.2-1.8)

*Savitz, D.A. and Calle, E.E. J. Occup. Med. 29; 47-51 (1987)

COMMENTS ON TABLE 2

Summary of leukemia risk estimates for electrical workers, adapted from the 1987 publication by Savitz and Calle. There is a clear indication of an elevated leukemia risk among members of this occupational group, especially for acute myelogenous leukemia. Unfortunately, these studies were poorly done and there was no effort to relate exposure to power-frequency fields and leukemia risk. Therefore no casualty was established between the presumed exposure to EM fields and cancer risk. Again, there is a clear need for one or more comprehensive epidemiological studies in which power- frequency field exposure is assessed,

as well as exposure to other potentially carcinogenic substances in the workplace (e.g., solvents such as benzene, etc..).

TABLE 3

DEFICIENCIES IN THE EPIDEMIOLOGICAL STUDIES
CONDUCTED TO DATE

Small sample sizes

Lack of quantitative dosimetry

Limitations of statistical methods used

Nonblind encoding procedures

Control groups either nonexistent or not appropriately matched for age, sex, socioeconomic class, or urban/rural residential status

Failure to account for confounding factors such as smoking habits and exposure to industrial pollutants of known carcinogenic potential

Most of the epidemiology studies conducted to date have had several methodological flaws, as summarized in this table. The third item refers to the use of proportionate mortality ratios (PMR's) in most of the studies on occupational exposure to power-frequency fields and cancer risk. PMR can be a very misleading index of cancer risk. For example, if the overall disease incidence is less in the exposed group (the "healthy worker" effect), then the PMR would be greater than unity. This would lead to the incorrect conclusion that cancer risk was elevated among members of the exposed population of workers.

TABLE 4

LEUKEMIA MORTALITY RATES AMONG CHILDREN AND
PER CAPITA ELECTRIC POWER CONSUMPTION IN THE
UNITED STATES

<u>Year</u>	<u>Power Consumption (Kwh per capita)</u>	<u>Mortality from Leukemia (per 10 child-years)</u>
1950	2164	4.0
1960	4194	4.1
1970	7510	3.2
1980	10,070	1.8

COMMENTS ON TABLE 4

Although electric power consumption in the U.S. increased about 5-fold during the three decades from 1950 to 1980, the childhood leukemia mortality decreased two-fold during the same period. [The major decrease between 1970 and 1980 is probably due to great improvements in cancer treatment during that period.] If increased power use is correlated with increased exposure to ELF electromagnetic fields, than one might expect to see an increase in the leukemia incidence, especially during the period 1950-1970 when the clinical treatment of childhood leukemia was not improving significantly. However, there is no indication that an elevation in cancer risk occurred during the period when power usage was rapidly increasing in the U.S.

TABLE 5

INDUCED CURRENT DENSITIES AND BIOLOGICAL EFFECTS

Current (mA/m)	Biological Effects	Projected Health Risk
< 10	Magnetophosphenes and other minor effects	None
10 - 100	Possible tissue effects (including acceleration of bone fracture reunion)	Small (possibly none)
100 - 1000	Thresholds for neuronal and neuronmuscular stimulation	Possible
> 1000	Extrasystoles, ventricular fibrillation muscular tetany and respiratory effects	Define

COMMENTS ON TABLE 5

This table is a general summary of the available laboratory data on the biological effects of ELF electromagnetic fields. The results of limited human studies are also included, except for the controversial cancer issue. It is important to recognize that the threshold current density for producing reproducible biological effects is about 10 mA/m . To produce currents of this magnitude in the human torso by magnetic induction would require a 60-Hz field with an intensity of about 2 Gauss (0.2 millitesla). This field level is approximately 3 orders of magnitude greater than the 60-Hz magnetic fields routinely encountered in the residence or workplace. If a relationship between cancer risk and power-frequency field exposure exists, then the mechanism(s) of field interaction underlying this effect is very difficult to conceive.

CHAPTER IV

DISCUSSION OF THE LITERATURE

This section presents a thorough discussion of the evaluated literature with emphasis on the main issue areas outlined in Chapter I.

Physical Hazards, Including Electric Shocks and Effects on Electronic Medical Devices

The two principal issues related to this topic are: (1) ELF field effects on medical devices, especially cardiac pacemakers; and (2) electric shock phenomena. These issues will be discussed separately, and analyzed for relevance to ELF communication systems.

A. Cardiac Pacemakers

Modern microprocessor-controlled pacemakers operate in a "demand" mode, in which electrical stimuli are delivered to the heart only if it fails to exhibit intrinsic activity. Two different configurations of electrode leads are used in modern pacemakers: the "bipolar" design in which both electrodes are implanted in the heart with a separation of less than 3 cm, and the "unipolar" design in which the cathode lead is implanted in the heart and the pacemaker's case serves as the anode. Only the "unipolar" design has been found to be sensitive to electromagnetic interference (EMI) with pacemaker functions. This interference results from the significant separation of the anode and cathode in a "unipolar" pacemaker, which provides a large antenna for the reception of EMI. Of the approximately 500,000 individuals in the United States who have implanted pace

makers, about 50 percent have the "unipolar" variety.

Demand pacemakers exhibit two characteristic malfunctions in response to EMI. The first type of malfunction is characterized by an aberrant pacing rate, with either irregular or slow pacing. The second type of malfunction results from the modern pacemaker's noise detection circuitry, that causes the pacemaker to revert to a fixed-rate pacing mode (the "reversion" mode) when EMI is sensed. In this mode, the cardiac stimuli provided by the pacemaker can be competitive with the heart's own endogenous signals. Only a few types of commercially available pacemakers have sophisticated noise rejection circuitry that can circumvent the two types of malfunctions described above. The great majority of modern pacemakers (greater than 90 percent) are responsive to EMI with differing degrees of sensitivity.

During the past year RDL has reviewed four publications that described in vivo tests of pacemaker sensitivity to EMI. Hewson (1985) studied the relative vulnerability of pacemakers that used two different modes of response to EMI: (a) each sensed interference event resets a timer; if the output of the timer remains high due to EMI for a time longer than the cardiac pacing interval, then the pacing pulse generator is set to deliver pulses at a fixed rate (the asynchronous pacing mode); (b) EMI is recognized only during the last 100 msec of the refractory period of the cardiac pacing cycle; if an EMI event occurs more than once during this period, the refractory period is extended to equal the pacing interval so that a pacing pulse is delivered. It was demonstrated from in vivo tests that pacemakers using method (b) were vulnerable to inhibition by the fields of RF diathermy units, whereas the pacemakers using method (a) as a response to EMI were not inhibited by the RF diathermy fields. Studies on 50 pacemaker patients exposed to 50-Hz electric fields in a hospital setting showed that two models

experienced EMI in fields as low as 2 kV/m, corresponding to body currents of 26 uA (Male, 1985) . Some models showed irregular or slow pacing at field levels above 5 kV/m, while other models were not vulnerable to fields as high as 20 kV/m. In all cases the pacemakers resumed normal functioning as soon as the electric field was removed. In a large survey conducted by the British Pacing Group on 25,000 pacemaker patients (Gold, 1985), only 11 documented cases of pacemaker malfunctioning due to EMI were recorded. The author speculated that the effects of EMI on pace maker operation may be so transient in many cases that the patient is unaware of the problem.

Four publications were reviewed by RDL in which the authors reviewed the various sources of EMI that can affect pacemaker functioning (Crick, 1985 ; Furnass and Lago, 1985 ; Gebhardt-Seehausen and Recker, 1984 ; and Timms, 1985). In a hospital environment, the common sources of EMI include electrocautery equipment, faulty ECG monitors, and ungrounded x-ray units.

Medical NMR imaging units also produce static and time-varying magnetic fields than can interfere with pacemaker operation. Industrial sources of EMI include unsuppressed commutators and ignition systems, transformers, electric motors, arc welding units, pulsed RF radiation sources, and strong FM broadcast signals. In the public domain, a risk of pacemaker interference is posed by antitheft devices, airport weapon detection systems, electric door openers, microwave ovens, and faulty grounding of appliances. In general, the fields that influence pacemaker performance are significantly higher in intensity than the levels encountered in air in the vicinity of an ELF antenna.

B Orthopedic Metal Implants

Farwell et al (1986) tested the rate of corrosion of orthopedic metal implants

when they were exposed to a high-intensity pulsed magnetic field similar to the fields used medically to stimulate bone fracture reunion. They found no increase in the rate of corrosion in the exposed relative to the sham-exposed metallic implants while immersed in a physiological saline solution.

C. Electric Shock Phenomena in Humans

Four papers reviewed by RDL during the past year have reported levels of human sensitivity to electric shocks resulting from contact with ungrounded objects than can accumulate a large electric charge. Research by Maamarbachi et al. (1986) observed values of the "let-go" current threshold of 12 mA for men and 9 mA for women. Currents that cause cardiac fibrillation were found to range from 20 to 100 mA for strong electric shocks lasting 0.3 msec to 5 sec. They also found that currents in excess of 0.5 A could cause electric burns whose depth depended upon the direction of the applied voltage and current flow. Reilly and Larkin (1985) also observed significant differences in the sensitivity of men and women to electric shocks, which can be explained on the basis of body size differences. These authors have developed a neural excitation model to explain the observed electric shock thresholds in human subjects. Another model based on the solution of electric field equations describing current densities in the human body has been developed by Chuang and Chen (1986). Male et al. (1985) have concluded that the regulation of human exposure to power-frequency fields from high-voltage installations should be based on the threshold voltages and currents that produce perception and microshocks. They argue that the upper limit of power-frequency electric field exposure should be set at 10 kV/m. This level is well above the maximum field level of 160 V/m present in air near an ELF antenna.

D. Electric Shocks in Farm Animals

Three studies on the sensitivity of farm animals to microshocks resulting from stray voltages and currents were reviewed by RDL during the past year. Gorewit et al. (1985) and Drenkard et al. (1985) studied the response of dairy cows to 60-Hz currents of 4 to 8 mA strength applied to feeders and watering devices for 5 sec. during each 30 sec. interval. They found that an 8 mA current affected blood levels of cortisol, oxytocin and prolactin, which may be the cause of decreased milk production when microshocks are experienced by dairy cows. Cardiovascular processes were affected transiently by currents at the level of 4 mA and above. Gustafson et al. (1986) reported that swine could detect stray voltages as low as 0.2 V. They found, however, that current levels of 3 to 4 mA from water sources were required to affect drinking time or total water consumption by pigs. The relatively high levels of current required to affect water consumption

and drinking performance by farm animals are unlikely to be encountered in the vicinity of an ELF antenna.

Therapeutic Effects

During the last two decades the efficacy of pulsed magnetic fields for stimulating the reunion of bone fractures has been tested extensively in clinical trials. Compared to earlier procedures in which electrodes were inserted directly into bone to produce electrical current that accelerate fracture healing, the use of pulsed magnetic fields has several distinct advantages: (1) the fields are applied external to the body surface by Helmholtz coil applicators, and so there is no risk of surgical trauma or infection; (2) there is no problem with electrode polarization or the release of toxic products into tissue; and (3) the induced field in bone is

reasonably uniform. Beginning in the early 1970's, several clinical trials indicated considerable promise for the facilitation of bone fracture healing by the application of pulsed magnetic fields with repetition frequencies in the ELF range.

In the last year, RDL has reviewed 6 reports of clinical studies on the facilitation of bone fracture reunion by ELF pulsed electromagnetic fields. Two of these articles reviewed the results of clinical trials conducted prior to 1984 (Bassett, 1984 and 1985). In more recent studies, Dal Monte et al. (1985) reported on the favorable results of a large clinical trial conducted in Italy. A total of 248 patients with pseudoarthroses and delayed bone fracture reunion were treated 10 hr/day with a pulsed magnetic field applicator operating at a 75 Hz repetition frequency. Bone healing was observed in a total of 208 patients (84%) with an average treatment time of 3.7 months. Relative to untreated control patients, the increase in successful treatments of bone fracture nonunions was statistically significant. In two other clinical trials, Frykman et al. (1986) and Aaron (1985) reported improvements in the treatment of fractures of the scaphoid and femoral bones, respectively, as a result of treatment with pulsed magnetic fields. Brighton and Pollack (1985) reported the results of a clinical trial in which a capacitatively coupled, 60-kHz electric field was used to stimulate bone fracture healing. They reported that 77.3% of the 20 patients achieved solid bone fracture reunion after an average of 22.5 weeks of treatment, which they regarded as a significant result. In a separate study, Vresilovic et al. (1985) have developed a theoretical model to predict the currents induced within a bone fracture by a capacitatively coupled, 60-kHz electric field.

In another study with human subjects, Chogovadze (1986) reported that neuro-circulatory dystonia was improved as a consequence of treatment with a 300-Hz,

5 mT magnetic field. Based on observations with 42 hypotensive patients and 23 hypertensive patients, the author reported that adrenalin and noradrenalin levels were restored toward normal levels. The hypertensive patients exhibited a significant decrease in systolic blood pressure as a result of pulsed magnetic field treatment.

A total of 10 reports were also reviewed on experimental animal studies in which pulsed fields were used to treat bone fractures and various types of injuries to nonosseous tissues. Bramlage et al. (1985) and Enzler and Perrent (1984) studied the effects of pulsed fields on the healing of leg bone fractures in horses and dogs, respectively. In neither of these studies was a significant effect of the pulsed field noted on the rate of fracture healing based on x-rays and tests of the mechanical strength of the fractured bones. Armstrong et al. (1985) failed to observe an effect of a capacitatively coupled electric field on the growth of leg bones in rabbits. In general, laboratory studies on experimental animals have not supported the claims based on human clinical trials that pulsed EM fields facilitate bone growth and fracture reunion.

In studies on the healing of soft tissue injuries in experimental animals, Krauss (1984) reported that skin burns in rats healed more quickly when treated with pulsed fields. It was also reported by this author that high intensity, 20-Hz sinusoidal magnetic fields retarded the growth of tumors in rats. Herbst and Bryant (1987) also reported that pulsed field therapy improved the healing of skin wounds. Studies by Leaper et al. (1985), however, demonstrated that a static magnetic field of 40 mT intensity produced by a magnetized "Energy Pak" foil had no effect on the healing of skin wounds in rats. Two studies on the regeneration of injured nerves in mice and rats (Buchner and Kleinbeckel, 1986) and Greathouse, 1985 failed to reveal any beneficial effect of pulsed magnetic

field therapy. In contrast, studies on inflammatory reactions induced by carageenan, Freund adjuvant, and Sephadex gel in rats indicated that the acute phase of the reaction was less severe in animals treated with pulsed magnetic fields (Zecca et al., 1985 and Zecca and Ferrario, 1987).

A total of 4 in vitro studies that are relevant to the use of pulsed EM fields for accelerating the healing of injuries to bone and soft tissues were reviewed by RDL during the past year. Siskin et al. (1985) reported that the growth of dorsal root ganglia in chick embryo cultures was enhanced by the application of both pulsed EM fields and DC electric currents. Jackson (1986) observed an increased rate of cell proliferation and protein synthesis in chick embryo cultures exposed to pulsed fields relative to control cultures. In contrast, Coulton et al. (1985) found no increase in cultured chick tendon cells exposed to pulsed magnetic fields. Liu et al. (1986) also found no increase in cell proliferation or protein synthesis in cultured chick tendon cells exposed to pulsed fields. In general, the results of in vitro studies described above, the intensity of the pulsed fields and capacitatively coupled fields used to facilitate the healing of bone fractures and soft tissue injuries are significantly above the field levels associated with ELF communications system. As a consequence, there is no direct relevance of these studies to the biological effects resulting from exposure of humans or lower animal species to the fields present in the vicinity of an ELF antenna.

Cellular and Physiological Studies

A. In Vitro Cellular Studies Including Membrane And Extracellular Interactions

The literature reviewed on cellular, cell membrane, tissue, and whole animal

interactions with electric and magnetic fields may be grouped into cell biology studies, genetics studies, studies of calcium-related phenomena, neurophysiological, neuroendocrine and physiological studies. In particular, the cell biology studies commonly tested for biochemical responses, while the in vitro cellular genetics studies involved gene transcription and translation. Genetic studies in the whole animal tested chromosomal and reproductive endpoints. The calcium studies, sometimes in relation to the "cyclotron resonance" model, tested frequency- and field strength-specific effects.

Overall, the research has been marked by data which indicate that relatively weak low frequency magnetic fields have significant effects on cell functions. Many investigators also found that exposure-response relations were complex, supporting the concept of frequency or amplitude windows, although overall, the windows are often inconsistent from one study to another. In the main, the results of the last twelve months have augmented previous research directions rather than striking out in new directions. Because the mechanisms of interaction are largely unknown, and because of the complicated dosimetric patterns, it is significant that many of the unusual characteristics reported in previous years has been supported by more work, thereby strengthening the data base. Although recent epidemiological data suggest that very weak (1 mG) sinusoidal magnetic fields may influence the development of cancers, there have been no studies conducted at that level. However, the magnetic fields near an ELFCS antenna are several orders of magnitude larger, and experiments with magnetic fields of 0.1 and 1 mT are generally relevant to the ELFCS.

The evidence for magnetic field effects on gene transcription and translation, although still conducted at only one laboratory, has been significantly extended. There is now significant evidence of fundamental interactions with

the genetic apparatus by both pulsed and sinusoidal magnetic fields at levels of about 1 mT. Other work in genetics appears to show effects on DNA transcription and translation. In general, studies with pulsed magnetic fields (PEMFs), often using the particular waveforms of the Bi-Osteogen apparatus (Electrobiology, Inc.), have emphasized effects on cell biochemistry and cellular immune responses. Typically, the PEMFs had peak intensities of about 1 to 5 mT and fast rise times capable of inducing electric fields of 0.1 to 1 V/m.) Recent evidence shows distinctive changes following exposure to 72-Hz magnetic fields. A number of studies have emphasized that, exposure duration or repetition of exposure are important experimental parameters. Positive results with sinusoidal magnetic fields are fewer, but several significant results were reported.

The literature reviews in 1987 included a greater number of citations from East European countries, including the USSR. Many of these studies appear to involve strong (0.01 to 1 T) static magnetic fields and powerline magnetic fields.

Goodman and co-workers reported (Goodman et al, 1986; 1987; 1987a) additional findings on the translational changes due to sinusoidal and pulsed magnetic fields at several frequencies, including 72-Hz. The proteins observed on 2-D gels indicated there are frequency-specific changes in gene transcription. The magnitude of changes in gene transcription (as measured from autoradiograms) was often as large as 5 or 10-fold.

Reese et al. (1987) reported no direct damage (single strand breaks) to cellular DNA of unstimulated human lymphocytes exposed in vitro to combined electric (38 V/m in the medium) and magnetic (20 G) fields. Similarly negative findings on lymphocyte DNA sister chromatic exchange rates for in vitro exposures to a 5

mT field were reported by Brinkmann et al. (1987), but they did find slight effects on DNA repair and growth rates.

Byus et al. (1987) reported changes in the cellular growth-regulating enzyme, ODC, following exposures at 10 mV/cm (60-Hz), and also at 0.1 mV/cm. Effects were critically dependent on duration of the field exposure. This report is a significant new finding because it suggests a biochemical mechanism which may mediate field effects on cell growth, possibly including steps of the cancer process. Cain et al. (1987) investigated ODC in bone cells and fibroblasts exposed to 10 mV/cm 60-Hz electric fields with the observation of changes of up to 2-fold. These results were compared with increased ODC following exposures to tumor promoting agents. Brinkmann et al. (1987) reported no influence of a 5 mT field on growth of tumor cells or human lymphocytes.

Using PEMFs for an intermittent, 6h on/6h off exposure, Ryaby et al. (1987) observed increased activity of the enzyme tyrosinase in melanoma cells. Studies of cAMP and cAMP-dependent protein kinases indicated inhibition at the GTP binding protein. Changes in cAMP and kinase levels were up to five-fold within 30 min following cessation of field exposure.

In another paper bearing a significant finding, Takahashi et al. (1985) reported on changes in DNA synthesis after exposures of CHO cells to PEMFs. Effects were dependent on field strength (maximum effect at 0.2 G), frequency, and pulse width. A reversal of effects was found when the field strength was increased to 4 G.

Studies of brain tissue calcium metabolism continue to be performed in several laboratories in order to establish additional phenomena and the

mechanisms of action. Blackman et al. reported (1986) that calcium efflux from chick brain depended on the frequency of field exposure during the incubation period. Thus, eggs exposed during incubation to 50-Hz magnetic fields differed in their response from 60-Hz pre-exposed tissue. Brand et al. (1986) demonstrated that calcium efflux from the left brain half exceeded efflux from the right brain half at significant levels in about 1/3 of the tests, but found no field dependent effects. Lee et al. (1987) exposed chick brain tissue to 16-Hz amplitude modulated rf fields using techniques similar to original studies by Bawin et al. and Blackman et al. Unlike those authors, they found field-dependent effects at reduced temperature (26.5 C), but not at 37 C. Bellossi (1986) reported no effects on calcium efflux of chick brains following exposures to strong static magnetic fields (0.2 to 0.9 T).

Liboff et al. (1987) found uptake of ^{45}Ca into lymphocytes was affected by a 14.3 Hz magnetic field in a manner supporting the cyclotron resonance model for interaction of static and time varying magnetic fields. A strong amplitude window was also observed suggesting the magnitude of the ac field must be similar to the parallel component of the static magnetic field (approximately 0.2 G). A theoretical model for ion motions which is consistent with observations of resonant behavior was described by Chiabrera et al. in an abstract (Chiabrera et al, 1987).

Tests of immune system function by Lyle et al. (1986) showed that lymphocyte cytotoxicity was affected by a 48 hour pre-exposure to 60-Hz electric fields of 1 or 10 mV/cm, but not by exposure during the cytotoxicity assay (during which the lymphocytes recognize and attack the target cells). Winters et al. (1986a) found that in vitro 60-Hz magnetic fields (1 G rms) significantly improved virus resistance. Cossarizza et al. (1987) found significant changes

in DNA synthesis and interleukin-2 levels in mitogen-stimulated human lymphocytes exposed to PEMFs.

The final report to the New York State Power Lines Project by Winters (1986) indicated changes in proliferation of normal cells, and coordinated changes in DNA, RNA and protein synthesis. However, the most striking data, (e.g., Winters, 1986, or Phillips et al 1986, 1986a ; Phillips, 1986) are indications from the soft agar cloning of cancer cells that there may be effects on cell proliferation and on cell surface receptors following exposure to sinusoidal 60-Hz magnetic fields.

Sheppard et al. (1987) reported effects on the timing of electrical activity in invertebrate pacemaker neurons exposed to 60-Hz, 10 mV/cm electric fields. Changes leading to both increases and decreases in the interval between activity were seen, but intervals were lengthened to a greater degree.

Sakharova et al. (1977) reported changes in neurotransmitter contents of rat brains exposed in vivo to 200 G, 50-Hz magnetic fields. Rein et al. (1987) found inhibition of norepinephrine uptake in nerve cells following exposures to a PEMF.

Wound healing was improved as a result of a significant reduction in necrosis for the PEMF-exposed rats (Herbst et al., 1987). Osteogenesis in chick embryonic bone was improved by PEMFs despite low O₂ tension in the bathing medium (Jackson et al., 1987).

Cohen et al. (1986) found no field effects on cell division in peripheral lymphocytes exposed to joint 60-Hz electric and magnetic fields. Studies of sister chromatid exchange and chromosome breaks (Cohen, 1986) were negative

for effects of exposure.

B. In Vivo Physiological Studies Including Neural And Neurophysiological Effects

In vivo electric and magnetic field exposures to test for cytogenetic effects were negative on many factors such as sister chromatid exchange rates, sex ratio, weight gain, and bone marrow cell responsivity (Benz et al., 1987). However, small, but partially replicated effects on litter mortality and litter size were found. The pattern of results does not permit conclusion that those effects were field-related.

In contrast, the controversial evidence for developmental abnormalities in chicks exposed to pulsed magnetic fields received support from observations reported by Juutilainen et al. (1986, 1986a). They exposed chicken embryos to 100-Hz sinusoidal and pulsed magnetic fields (1.3 uT). Unipolar magnetic fields had no effect, but bipolar square waves were effective. Contrasts of the relative effectiveness of various fields led the authors to conclude the effects are due to the magnetic field directly and not the induced magnetic field. In tests of the frequency dependence of developmental abnormalities, they found that frequencies of 16.7 to 105 were effective for field strengths between .13 and 1.3 uT. Amplitude windows were reported such that a field of 130 uT was less effective than a weaker field. These results generally support the original work by Delgado, Leal and Ubeda, and are in contrast to reports by Maffeo et al.(1984) and Siskin et al. (1986) who found no developmental abnormalities.

Quinlan et al. (1986, 1987) compared neuroendocrine responses of rats exposed

to high voltage 60-Hz fields and those given classical stressors such as footshock. They concluded that the mild, transient responses to electric fields cannot be considered a stressor.

Frazier and Anderson (1987) found no in vivo effects in tests of rat immune responses to antigens. In contrast PEMFs inhibited DNA synthesis in mitogen-stimulated human lymphocytes (Mooney et al, 1986).

Conti et al. (1985) found that despite some alterations in the cells of the immune system and fetal weights, 50-Hz electric field exposures had no observed deleterious health effects on rats, dogs or rabbits nor on their progeny. Similarly, Seto et al. (1986) found small changes in the blood of exposed rats, but also did not find pathologic changes.

Lotz et al. (1986) reported that over four years exposure to low level electric (6 to 30 V/m) and magnetic (1.2 to 2 G) fields had no effects on growth, development or health of rhesus monkeys. This extensive test in a non-human primate provides significant evidence for the absence of deleterious health effects at these low field strengths.

Blackwell (1986) found a slight synchronization of brain cells to weak 15- and 30-Hz electric fields (100 V/m in air). This finding indicates a potential interference of sinusoidal fields with ongoing neural processes. Perhaps this may result in subtle changes in neural processing, but this cannot be evaluated.

Metabolism, Growth and Development

Studies on the effect of electric and magnetic fields on metabolism, growth and

development remain ambiguous. Reports appearing in the literature show both positive and negative effects of electromagnetic waves on biological systems. Often the results of one group have been difficult to replicate by another laboratory. In many instances, the effects observed are very small and hence statistically significant differences can only be shown after using large sample sizes. A typical example was the paper by Seto et al (1986) which reported that chronic exposure of rats to a high intensity 60 Hz electric field lowered the white cell, lymphocyte and eosinophil count in the exposed rats. However, these changes were termed 'subtle' and statistical differences could be shown only because the authors had used 135 rats in each of the control and exposed groups. In other studies using lymphocytes, Liboff et al (1987) showed changes in ^{45}Ca uptake in human lymphocytes after exposure to an AC electric field. The changes in ^{45}Ca uptake responded in a resonant manner when the amplitude of the applied AC field was varied. The authors used this effect to support their Cyclotron Resonance theory and did not attempt to discuss the significance of this effect.

Brinkmann et al (1987) were able to report no significant effects of 50 Hz magnetic fields on growth of tumor cells and human peripheral lymphocytes. In yet another study using lymphocytes, mitogen stimulation responses of spleen cells were used to measure membrane interactions and the subsequent initiation of DNA synthesis (Morris and McClanahan, 1986). Following exposure to 60 Hz fields (20 Gauss magnetic field intensity and 10 V/m electric field intensity), no consistent changes could be observed in the responses of the lymphocytes. An excellent review of the literature by Tompkins et al (1985) focused on studies observing potential ELF field effects on populations of cells of the immune system and on tests of immune system function. The conflicting pattern of findings reported in the literature was analyzed with respect to the possible influence of

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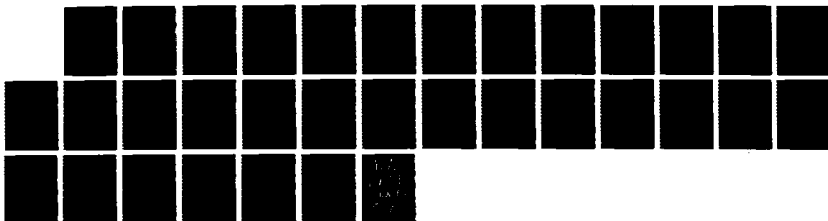
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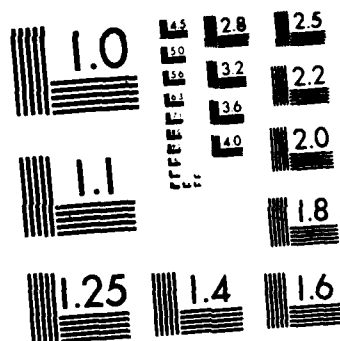
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stress related to ELF field exposure. The authors concluded that ELF field exposure may act as a low level stressor. In addition, variations in experimental conditions or the animals could account for apparent contradictions such as the increases and decreases in the number of circulating neutrophils. ELF suppression of immune functions in vitro were speculatively related to a reduction in calcium flux into the cell or alternatively may have been caused by altered mitogen receptors at the cell surface. The relatively scant literature on in vivo immune response was found to involve too many different experimental designs and field conditions to permit comparisons which would permit a conclusion of consistent effects. Based on studies by Morris and Phillips (1982) and Morris and Ragan (1979), the authors found good but not exhaustive evidence that long term exposure to 60-Hz electric fields at 100 kV/m (unperturbed) had no detrimental effects on the immune system.

Another review paper by Goodman and Greenebaum (1985) provided critical reviews of a large number of research papers concerning single cells exposed to electric and/or magnetic fields. The authors found substantial evidence that cation fluxes are sensitive to ELF fields and therefore suggest that there may be important changes in homeostatic relations governed by Ca^{2+} and Na^{+} as well as possible changes triggered by the second messenger role of Ca^{2+} . Additional experiments to address these issues were recommended, especially in relation to the fields of the ELF Communications antenna. The authors found "increasing evidence" for effects at the plasma membrane. They recommended substantiation of this model because it could be useful in extrapolation from laboratory results to assess environmental hazards. The authors concluded that "weak fields can affect and alter various cell functions. All effects were subtle except those observed at field strengths that would physically damage the cells. By subtle we

mean that the cell's normal functions are not halted or, as far as can be seen, irreversibly disrupted.....".

An evaluation of a number of studies which investigated the effects of 50 Hz fields on blood chemistry, growth and fertility showed only minor effects in a large group of different laboratory animals (Conti and Nicolini, 1985). The report further suggested that the ELFCS would not produce electromagnetic field (EMF) intensities severe enough to cause biological effects. Coulton et al (1985) reinvestigated claims from 4 different laboratories which showed significant effects of EMF by repeating the exact experiments under the described conditions. The first claim investigated was that noradrenalin release from previously preloaded PC12 cells was stimulated by magnetic fields. The second claim investigated was that protein synthesis and collagen accumulation in chick tendon cells in culture were increased by magnetic fields. Thirdly, the authors attempted to repeat the observation that sodium ion movement in isolated rat colon was affected by magnetic fields, and lastly, a commercially available product which produces magnetic fields and previously shown to cause vasodilation and increased skin blood flow was tested. This study reported no effects of magnetic or electric fields on any of the above systems, thus producing conflicting results. Negative results on protein synthesis in cartilage in response to applied electric fields (1-4 mA/cm²) were also reported by MacGinitie et al (1987).

In the same track, Bellossi (1986) investigated the claims of Blackman that static magnetic or electric fields affected calcium ion movements in chick brain slices. Using the same exposure system, conditions (200-900 mT) and techniques, this study was unable to show any differences in calcium efflux from brain tissues from control and exposed brains. Similarly Lee et al (1987) showed that calcium ion efflux from chick brain slices was unaffected by radiofrequency radiation, but

did change as a function of the incubation medium temperature ! Similar negative results were also reported by Brand et al (1986). When eggs of domestic chickens were exposed during incubation to 50 Hz and 60 Hz sinusoidal electric fields of intensities of 10 V/m and subsequent to hatching, the chick brains used to study calcium ion fluxes, it was found that only those eggs which had been exposed to 50 Hz but not 60 Hz fields showed changes in calcium ion efflux (Blackman et al, 1987). The physiological significance of this finding was not established, but it was concluded that EM fields could have profound effects on the developing organism. In this respect, Juutilainen et al (1986, 1986a) reported that chicken embryos had significantly more gross abnormalities when exposed throughout early developmental stages to 100-Hz sinusoidal pulsed or square bipolar waveforms greater than 1 A/m (0.013 Gauss). Unipolar square waveforms had no effect. In contrast with findings reported previously by Delgado and coworkers, effects were generally absent at 0.1 A/m and there was little evidence for intensity window effects. Overall, the intensity dependence indicated a threshold at 1 A/m. Tests of the rate of embryo development revealed no retardation or acceleration produced by exposures to pulsed and bipolar waveforms. Among unexposed controls, "strong" abnormalities averaged 5%, compared to 26-28% among exposed eggs. Measurements of egg temperature with the magnetic field coils energized indicated no heating effect of the coils. The largest number of developmental defects were in the nervous system with lesser, but significant amounts in the vessels, heart, somites and overall embryo shape. As always, data that directly conflicts these findings was reported by Maffeo et al (1984). In this study, fertilized chicken eggs were incubated for 48 hours while exposed to pulsed trains of square wave magnetic fields with a duration of 0.5 msec and pulse repetition rates of 100 or 1000 Hz at magnetic flux densities of 1.2 and 12 uT. Measurements made at sacrifice were for gross structural abnormalities of primary

vesicles, anterior neuropore, optic vessels, auditory pits, truncal nervous system, heart, somites and blood vessels. There were no differences between exposed, sham-exposed and control eggs. Sisken et al (1986) exposed fertile chicken eggs to electromagnetic field strengths of two different intensities (0.16 mV/cm and 1.5 mV/cm) for either a 24 hour period or a 7 day period. Neither signal when applied continuously for the first 7 days of development or for the first 24 hours of development produced a significant increase in the incidence of malformations of the embryos.

In a study that was of extreme relevance to the ELFCS, Lotz et al (1986) studied growth of rhesus monkeys exposed to electric and magnetic fields (6.35 V/m to 28.45 V/m and 0.118 mT to 0.203 mT) for 22 hours a day for 54 months. There were no differences in growth rates of exposed and control animals in this study. A few parameters that showed statistically significant differences in the group versus time interaction were not correlated with one another and were judged to be isolated chance occurrences with no physiological significance.

In reviewing the literature, Delgado (1985), reported the following bioeffects of extremely low frequency electromagnetic fields :1) bacterial growth of *Lactobacillus* was inhibited by pulsed magnetic fields of 40 Gauss, 26 Hz; 2) Exposure of male *Drosophila* for 70 hours to 16 Hz pulsed magnetic fields of 35 Gauss produced a significant sex-linked recessive lethal mutation. 3) The unitary discharge of the crayfish stretch receptor was influenced by the application of pulsed magnetic fields. 4) Teratogenic effects were produced by exposing developing chick embryos to pulsed magnetic fields with intensities as low as 0.01 Gauss. Pulse shape and time of development were critical to the observed effects. The mitotic index was also influenced. 5) In monkeys, central nervous system excitability was influenced by applying fields focused on the cerebellum. However, the exposure

fields and intensities reported to produce these biological effects are not characteristic of the ELFCS.

A number of studies (Cain et al, 1987; Byus et al, 1987 ; Cain et al, 1985 ; Adey et al, 1986) have been carried out to study the effect of electromagnetic fields on membrane activities and the subsequent modulation of cellular components. In particular, the activity of ornithine decarboxylase (ODC) in bone cells. The results have either been negative (Adey et al, 1986) or positive (Cain et al, 1987) or both (Byus et al, 1987). Since the increased activity of ODC after exposure to EM fields is similar to that seen after exposure to tumor promoting agents, it has been suggested that EM fields could be acting as tumor promoters (Adey et al, 1987). However, no direct evidence has been provided to date. Leung et al (1987) did however report that chronic exposure of rats to 60 Hz (40KV/m) electric fields affected mammary tumor development induced by 7,12-Dimethylbenz(A) Anthracene (DMBA). Franceschi et al (1986) reported that exposure of human lymphocytes to ELF magnetic fields enhanced phytohemagglutinin induced blastogenesis of the lymphocytes. However, the data were presented only as an abstract form, and the number of donor samples was small. Similar results were also reported by Cadossi et al (1986) who used fields at 75 Hz frequency with a peak intensity of 2.8 mT. In studies using cultured plant cells, Jones et al (1986) investigated the effects of PEMF (15 Hz; 5 mV) on the induction of phenylalanine ammonia-lyase (a marker for differentiation in the French bean). The PEMF was applied for 12 hours for the first day of culture, and in cycles of 6 hours on/ 6 hours off for the next 8 to 10 days. There was a significant increase in phenylalanine ammonia-lyase activity in the exposed cells and this increase corresponded with an increase in the number of differentiated nodules. Date and Kaneko (1986) exposed HeLaS3 cells grown in culture to a 100 Hz magnetic field

of 0.6 Gauss and showed an acceleration in the growth rate of the HeLaS3 cells compared to the unexposed control cells.

Still other studies on cell metabolism were reported by Jones and Ryaby (1986) and Ryaby and Jones (1986). Exposure of melanoma cells to 15 Hz fields of intensity 0.1 Gauss/usec and 1 mV/cm caused a significant decrease in cyclic AMP levels and a 3-fold decrease in cAMP dependant protein kinase activity. Measurements of protein phosphorylation showed an increase in phosphorylation of a 52 kD class of protein after only a 30 minute exposure to the fields. There were other time dependent changes in phosphorylations of certain proteins. Although the proteins are not clearly identified, it can be stated that EM fields can regulate cellular phosphorylation mechanisms.

Exposure of rat aortas to constant magnetic fields of 0.008 T or 0.15 T in a 24 hour rhythm, 1 hour per day, 7 days per week for 7 weeks showed a dose dependent increase in the level of prostacyclin (Gorczynska and Wegrzynowicz, 1986). This increase in prostacyclin content could not be correlated to the time of exposure. However the authors suggested that such an exposure system could be used beneficially in clinical work to induce prostacyclin in post-operation states.

In other studies, plant roots are being used as model systems to study the mechanisms by which EMFs affect cells. Roots have representative embryonic cells at their tips which differentiate and become larger as the root grows. The general hypotheses tested assume that the site of action of EMF effects is the cell membrane. Perturbations of root growth rate is related to a change in membrane function in which larger cells should have a larger induced transmembrane potential (Ionue et al, 1985). To be effective, the applied field must induce a transmembrane potential that is a significant fraction of the cell's resting mem-

brane potential. These assumptions were supported by theoretical studies which predict that a time-dependent magnetic field that induces a 10 mV change lasting for milliseconds should significantly change cell membrane conductivities and induce change. Electric field induced effects in onion roots and human erythrocytes occur at cell membrane when the induced transmembrane potential ranges between 3-7 mV (Brulfert et al, 1985). The threshold was an applied field of 60 hz, 300 V/m. Larger root cells were demonstrated to be more sensitive than small cells by studying roots from different species of plant (Brayman and Miller, 1986), and by comparing sensitivities in cells of different sizes among the same root tip (Brayman and Miller, 1986). Both studies utilized 60 Hz, 200-300 V/m fields with the threshold for producing effects varying with root cell size. Strong magnetic fields (0.5-1.8 T) were reported to disrupt and inhibit the pattern of growth in bean coleoptiles (Brown et al, 1986).

Reproductive Effects

Studies of potential reproductive effects of ELF electromagnetic fields continue to receive much greater attention from laboratory scientists than from epidemiologists (in contrast to the situation for studies of carcinogenic effects). The basis for this is the relative absence of epidemiologic data (either positive or negative) regarding reproductive damage but the presence of several laboratory studies on chick embryos and other species suggesting that such exposures can adversely affect development.

The only human studies of reproduction noted in this year's literature were relatively minor. A second-hand report on the study of VDTs and miscarriage was noted (Anonymous, 1986d), with some suggestion that prolonged exposure increased miscarriage frequency. The only other report is a translated abstract

concerning sudden infant death and proximity to electrical lines (Eckert, 1977) in which the author clarifies his statements. Neither of these adds to the literature on epidemiologic studies of reproductive consequences of ELF electromagnetic field exposure.

Studies of reproductive performance of dairy cows exposed to AC power lines were reported (Algers et al, 1986; Martin et al, 1986). Neither study (both of which were large and well designed) found any indication of diminished performance. Experimental studies of mammals were conducted as well (Conti et al, 1985 ; Mahmoud and Zimmerman 1984), with some suggestion of a reduced number of pregnancies among rats exposed to electric fields, but not among pigs. Developmental defects were reported by some who assessed the effects of magnetic fields on chick embryos (Juutilainen, 1986, 1986a; Blackman, 1986) but not by others (Sisken et al, 1986). As research becomes increasingly specific in the exposure characteristics and biological responses assessed (Sisken et al, 1986; Juutilainen, 1986a), one would expect a convergence in the literature.

In a somewhat related study, conventional methods of incubating fish eggs failed when used with an introduced species of salmon, but succeeded when augmented by a weak magnetic field (Formicki and Winnicki, 1986). The effect was attributed to a slowing down of development to allow time for adaptation to a new environment. Inconsistent effects of pulsed EMF on chick embryo development were correlated with variations in the mean value of the earth's horizontal magnetic field (Leal et al, 1987). The results suggest that the earth's magnetic field could interfere with embryonic development, or modulate responses to the artificial pulsed field. The author claims that if true, "this could be a biological basis supporting the correlation between earth field reversals and mass extinctions".

Cancer Risk

Cancer continues to be the central interest among epidemiologists studying potential adverse effects of ELF electromagnetic radiation. This was fueled in part by the press coverage of the New York State Power Lines Project report which acknowledged the possibility that these exposures may affect cancer risk in children. As the interest grows, there is an increasing volume of epidemiologic and laboratory data pertinent to the evaluation of carcinogenic effects. The material included in the RDL Monthly Progress Reports from September, 1986 through August, 1987 was compiled and serves as the basis for this overview.

Several papers considered the relationship between residential exposure to electromagnetic fields from outside power lines and the occurrence of childhood cancer. Only one of these papers was actually published (Tomenius, 1986), with four reported in conference proceedings or contract reports (Coleman et al, 1985; Myers et al, 1985; Stevens, 1986; Savitz et al, 1986), and one progress report (87065). Given this situation, the conclusions must be presented as preliminary, awaiting the completion, final analysis, and publication of results. Tomenius's study of childhood cancer in Sweden (Tomenius, 1986) is an expansion of an earlier published abstract, and provides evidence that children who developed cancer lived more frequently near transmission lines and substations than controls. Furthermore, among children not near such installations, measured magnetic fields above 3.0 mG were over twice as frequent among cases as controls. This is an important study in that fields were measured and the study population was quite large. Though the conclusions go somewhat beyond the results, the data are suggestive of possible carcinogenic effects.

The other reports are more tentative. Stevens (1986) found no association

between adult leukemias and residential magnetic fields. Two British studies found little or no evidence that fields from transmission lines are associated with adult or childhood cancers (Coleman et al, 1985; Myers et al, 1985), though the rarity of elevated exposures weakens the strength of the basically negative results. Furthermore, there was some indication of higher exposures among leukemia cases in one study (Coleman et al, 1985). The results of the Denver childhood cancer study (Savitz et al, 1986; Barnes et al, 1986; Wachtel et al, 1986) were not presented in their entirety, but the data did suggest an association between wire configuration code (a magnetic field surrogate) and childhood cancer.

The occupational exposure studies related to cancer provide some further suggestions of increased brain cancer (Coggon et al, 1986; Thomas and Waxweiler, 1987) and leukemia (Gilman et al, 1985; Coggon et al, 1986) among "electrical workers." Studies which assessed occupational correlates of brain cancer which found no link were also reviewed (Burch et al, 1987; McLaughlin et al 1987) as well as a negative report on ocular melanoma (Gallagher et al, 1985). None of these papers included exposure assessment other than job titles so that none of the results (positive or negative) should be considered to be superior to earlier studies. Nonetheless, the impression that there is a non-random pattern of elevated brain cancer and leukemia among workers potentially exposed to electromagnetic fields continues to be strengthened.

A number of new studies at the cellular level pertinent to cancer risk were evaluated (Phillips et al, 1986a; Nordenson and Hasson Mild, 1987; 1987a; Adey, 1986 and Byus et al, 1987). Several of these reaffirm that ELF electromagnetic fields are not clastogenic, i.e. they do not break chromosomes. Although of value, the studies which address a possible cancer promoting effect (Byus et al,

1987; Adey, 1987) are of much more interest given the prevailing theory that if such fields increase cancer risk, they do so through some promotional effect. The often-cited limitation of interpreting the epidemiologic studies is the absence of a plausible mechanism by which such exposures could increase the occurrence of cancer; the work of Byus and Adey may represent the beginning of establishing such a mechanism.

In summary, there were no "breakthrough" studies of carcinogenic effects of ELF electromagnetic fields, but the literature grew in epidemiologic studies of residential and occupational exposures and in laboratory investigations of the effects of such fields on cellular processes related to cancer. Positive studies of residential exposure and childhood cancer were reported (Tomenius, 1986; Savitz et al, 1986), one equivocal childhood cancer study (Coleman et al, 1985), and two negative studies of adult cancers (Stevens, 1986; Myers et al, 1985). A similar mix of results was derived from occupational studies of leukemia and brain cancer. Laboratory studies confirmed the absence of chromosomal damage but the possibility of cell membrane effects resulting in cancer promotion. Overall, the possibility that cancer risk is increased was enhanced rather than diminished by the studies summarized here. Work in progress (e.g., Bowman et al, 1987) will help to resolve some of these uncertainties.

Behavioral Effects

The baboon has been used in both laboratory and free-ranging conditions to study the affect of ELF radiations on behavior. The US Department of Energy, the Central Research Institute of the Electric Power Industry, and the Southwest Research Institute have initiated a series of experiments to determine (1) the threshold of detection; (2) the threshold to induce avoidance-escape responses;

(3) affects of chronic exposure on operant conditioning, and (4) affects of chronic exposure on social behavior (Klein , 1985; 1986). Additional studies of the metabolites of neurotransmitters, pineal function, immune system and circadian rhythms have also been proposed, but it is not clear whether or not they have been initiated (Rogers, 1986). The approximate threshold of detection of 60-Hz EMF by baboons is reported to be 25-43 kV/m (Rogers et al, 1985). Exposure to 60 Hz at 60-72 kV/m did not affect appetite or operant behavior (Rogers et al, 1986; Orr et al, 1987). These findings challenge the assumption that ELF EMF's may be aversive and trigger physiological changes. with regard to social stress produced by EMF, baboons exposed to 60-Hz, 30 kV/m showed increased tension, passive affinity and stereotyped behaviors (Easley et al, 1987), but the responses decrease with time suggesting a transitory effect (Gyuk, 1987). While the baboons did become more active, there was no evidence of the baboon making postural adjustments to minimize EMF induction (Rogers and Smith, 1987). A single human experiment was reported in which the effect of a 50-Hz, 500 uA current injected through surface electrodes did not affect verbal reasoning skills or mood (Stollery, 1986). The EMF exposure was calculated to be equivalent to that received from a 30 kV/m vertical field.

Rats exposed to 35 kV/m HVDC did not exhibit avoidance behavior within the first 23 hours of exposure (Creim et al, 1987), and exposure of rats to a more intense 80 kV/m HVDC field did not produce taste-aversion learning (Creim et al, 1987a). The role of magnetic fields was explored by studies which found that static magnetic fields similar in strength to the earth's magnetic field can interact with weak oscillating fields to alter behavior (Thomas et al, 1985; 1986). The cyclotron resonance theory may be implicated since the experiment produced a cyclotron resonance condition for lithium which is known to play a role in human

behavior. This hypothesis was reinforced by tests with rats exposed to a range of frequencies from 45-78.9 Hz and voltages from 0-50 V/m (Stell et al, 1987). It was found that variability in responses to audio stimuli was greatest for rats exposed at 65.8 Hz which is close to the cyclotron resonance of lithium.

The citations summarized above are primarily abstracts of papers presented at meetings and/or work in progress. While critical reviews could not be done, the results claimed support the contention that EMFs in the vicinity of ELFCS are unlikely to produce adverse behavioral effects.

The ability to detect and orient to geomagnetic fields is now well documented for many organisms. However, the mechanism for this ability is unclear. The anatomy, physiology and development of iron containing cells in the honey bees were studied and shown to provide the physical ability to detect small magnetic fields (Kuterbach, 1985). Only specific cells (trophocytes) contain particulate iron. A migratory salamander appears to use a simple axial compass mechanism for simple orientation, but a distinct magnetoreceptive neural pathway with polar response pathways is also involved (Phillips, J. B., 1986). Salmon fry can also detect changes in the geomagnetic field, but there is no evidence that this ability is used as a navigational cue during migration (Kitamura et al, 1985). Similarly, magnetic fields similar in intensity to geomagnetic fields influence sparrow locomotion (Gordon, 1985). Data support the premise that birds must be moving to detect the field and that detection reinforces movement. Whether or not useful directional information is derived from magnetic fields was not clear. However, pigeon orientation can be perturbed by magnetic fields similar to the earth's field (Teyssedre, 1986). Pigeons treated prior to release in an artificial magnetic field that randomly oscillated in intensity and direction also became disoriented (Ioale et al, 1985). It was found that the shape of the wave, frequency and intensity

determined effectiveness with the strongest responses observed with sinusoidal waves of 100 and 500 Hz at 0.8 Gauss. Studies of homing by the hamster revealed no effect of geomagnetic fields on neurophysiological mechanisms or the ability to home (Etienne et al, 1986).

Studies of electroreception in elasmobranch fish showed that the apical cell membranes in the ampullae of Lorenzini constitute the electrical transducers which operate on common neurophysiological principles (Kalmijn et al, 1987). Electric organ discharges in electric fish contain wave-form specific information on sex, age and species, but how the fish process this information is not known (Max Westby, 1986).

While not pertinent to ELF radiations, it is interesting to note an undertaking by the Russians to develop specifications and criteria to protect the population from radar, TV and FM fields. The maximum allowable level of EM energy for long term settlement is given as 10 uW/cm (Tomashevistava and Solenyi, 1986, Karatchev and Kiev, 1987 and Soldatchenkov and Kiev, 1987). It is also of interest that reported abilities to modify human behavior with non-ionizing radiation has been cited by an activist group in England as the reason for various physical disorders (Anonymous, 1986). They claim they were harmed by non-ionizing radiation in order to force them to abandon their peace camp.

Ecological Effects

This section will cover a variety of studies on agriculture near high voltage transmission lines and on ecology.

The Electricity Energy Division of the US Department of Energy has supported comprehensive research into the effects of high energy electric fields (Klein, 1984).

Research conducted by the Bonneville Power Administration may represent the major effort in the US to determine the effects of electric power transmission by exposing plants and animals directly to power line EMF. A 1985 review of their findings includes a description of the electrical properties of AC and DC lines and the effects observed on plants, animals and people exposed to these fields (Lee et al, 1985). A general conclusion indicates that to date, with appropriate mitigation, no harmful biological effects have been observed under a variety of conditions. The report does recognize, however, unconfirmed findings by other investigative teams of possible associations between occupational and residential exposure to AC magnetic fields and cancer. Similar comprehensive studies have been undertaken in Italy by ENEL in cooperation with Italian Universities. Laboratory and field studies with 50-Hz EMFs looked for effects in mice, rats, dogs, rabbits and poultry (Conti et al, 1985). The conclusion was that 25 kV/m appeared to be a threshold for effects, which, if they occurred at all, were likely to be transitory or reversible. EMFs below 10 kV/m were considered unlikely to produce biological effects. On the basis of data such as these, the Florida Power and Light Company asked the State Supreme Court to overturn a \$1.6 million award to owners of land condemned for a 500 kV powerline-right-of-way (Anonymous, 1986a). However, the appeal was denied on the basis of expert testimony supporting the position that (1) there was a "reasonable basis" for residents to fear the health hazards posed by power line radiations and (2) property values had been lowered. Expert opinions to the contrary failed to influence the jury. The Florida Department of Environmental Regulation has now established an advisory panel to help develop standards to protect the public from Powerline EMF (Anonymous, 1986b). Other investigations are underway to determine how best to reduce potential affects of EMF (Murgatroyd, 1985; Lee et al, 1985).

The World Health Organization has issued Environmental Health Criteria 35 which deals with biological effects of ELF fields (Phillips, R., 1986). The analysis and conclusions are based on literature published through 1983. The conclusion was that it is not yet possible to make definitive statements about the safety or potential hazards associated with long term exposure to sinusoidal ELF fields in the range of 1-10 kV/m. the report recommends that exposure of the general population be kept as low as can be reasonably achieved. This key document has also been issued as an EPA report. Using the WHO Criteria 35 as a guide, a 220 kV/m powerline in Victoria, Australia was approved based upon the powerline meeting all WHO guidelines and lack of evidence of health risks (Anonymous, 1986c). The latter point was supported by expert testimony that animal studies do not support the reported link between ELF radiations and cancer.

Reported effects of nearby electric power transmission lines on livestock have stimulated much research, and guidelines for preparation of agricultural environmental impact statements have been proposed (Rumsey, 1985). A ten year cooperative study by American Electric Power and the Bonneville Power Administration found no significant affect on crops and livestock maintained within transmission line corridors (Roy et al, 1984; Mahmoud and Zimmerman, 1984). The findings of the first year (1986) of a multiyear study by Oregon State University show no affect on cattle or growth or yield of wheat and alfalfa grown under simulated farming and ranching conditions beneath a 500 kV-DC transmission line (Raleigh, 1987). These results were further substantiated by a study of productivity of dairy cows exposed to EMF from HVDC transmission lines in Minnesota (Martin et al, 1986).

Stray voltages in livestock holding facilities have been implicated in reduced productivity of dairy animals and swine. Two studies of milk production, health,

behavior and endocrine responses in cows (Drenkard et al, 1985; Gorewit et al, 1985) and one on drinking behavior in swine (Gustafson et al, 1986) show that stray voltages of 1-5 V producing more than 4.5 mA of current (mouth to hoof) cause an avoidance behavior which could account for reduced productivity. It is likely that when effects on livestock are reported, it is the result of behavior modification produced by extraneous currents at the feeder and waterers and not direct effects on the physiology of the animals. Studies done under transmission lines appear to minimize the use of conductive materials and thereby circumvent this phenomenon. All of these studies summarized were done with EMFs of much higher intensity than occur at ELF communication sites.

Few studies of the effects of ELF radiations on natural populations or communities have been reported. Research of the affect of 76 Hz fields produced by ELFCS on Peatland ecosystem (Stearns et al, 1986) and breeding bird communities (Niemi et al, 1986) are in progress in Wisconsin. The Peatland ecosystem study includes measurement of decomposition rates, foliar cation concentrations, and leaf diffusion resistance. No significant effects have been observed to date. The breeding bird study, as well as several other ecologically oriented studies not reported during this review period, are in progress. The latitudinal gradient of vegetation types along a disturbed transmission line right-of-way in Manitoba was described (MacClellan et al, 1986). The right-of-way reportedly transects six natural vegetation zones as it extends north. The plants within the corridor were found to differ in both species composition and physiogamy from the natural communities bordering the right-of-way. The right-of-way appeared to act as a conduit for invasion of cosmopolitan weedy species into previously unavailable northern sites. While the EMF and the scale of clearing for the right-of-way were undoubtedly greater than occurs at ELFCSs, the report lends credence to the

opinion that the detectable ecological effects of ELFCSs will likely be from construction and maintenance of right-of-ways rather than from ELF fields.

Amino acid metabolism in natural estuarine microbial communities in Chesapeake Bay was found to be reduced in the immediate vicinity of an EM pulser, but to be increased at distances as great as 200 m from the pulser (Jonas et al, 1986). These results were supported by laboratory studies. The EMF conditions were not clear from the abstract but it is unlikely that the findings are relevant to the ELFCS.

LITERATURE CITED

Aaron R K (1985). Treatment of Osteonecrosis of the Femoral Head With Pulsed External Magnetic Field. Proceedings of the 11th Annual Northeast Bioengineering Conference, Worcester, MA, March 14-15, 1985.

Adey W R (1987). Cell Membranes, Electromagnetic Fields and Cancer Promotion (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Adey W R (1986). The Sequence and Energetics of Cell Membrane Transductive Coupling to Intracellular Enzyme Systems. Bioelectricity and Bioenergetics, Vol. 15 : 447-456.

Adey W R, Bawin S et al (1986). Untitled. Annual Technical Report to Office of Naval Research for Project # RR 04108, July 1986.

Algers B and Hultgren J (1986). Cows Under 400 KV Power Lines-Effects on Ovulation and Fertility. Svensk. Veterinartidning, Vol. 38 : 229-235.

Anonymous (1986). Zapping at Greenham Common. Microwave News, Sept./Oct. 1986

Anonymous (1986a). Florida Power Line Award Appealed to State Supreme Court. Microwave News, Sept./Oct. 1986.

Anonymous (1986b). Updates : Powerlines. Microwave News, Sept./Oct. 1986.

Anonymous (1986c). Updates : Go Ahead for Australian Power. Microwave News, Sept./Oct. 1986.

Anonymous (1986d). VDT : Miscarriage Risk, EPI Study. Microwave News, Sept./Oct. 1986.

Armstrong P F, Brighton C T et al (1985). The Inability of Capacitively Coupled Electrical Fields to Produce a Clinically Significant Acceleration of Longitudinal Bone Growth in the Rabbit Model (ABSTRACT). Orthop. Trans., Vol. 9 : 487-488.

Barnes F S, Wachtel H and Savitz, D A (1986). Magnetic Fields and Wiring Configuration (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Bassett C A L (1984). Biomedical and Biophysical Effects of Time-Varying Electromagnetic Fields. Orthopade, Vol. 13 : 64-77.

Bassett C A L (1987). Therapeutic Uses of Athermal, Time-Varying Magnetic Fields in Clinical Medicine (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Belloso A (1986). Lack of an Effect of Static Magnetic Field on Calcium Efflux from Isolated Chick Brains. Bioelectromagnetics, Vol. 7 : 381-386.

Benz R D, Carsten A R et al (1987). Mutagenicity and Toxicity of 60 Hz Magnetic and Electric Fields. New York State Power Lines Project, Contractors Final Report. Contract No. 218213.

Blackman C F, Benane S G et al (1986). Effect of Power Line Frequency Electric Fields on a Developing Organism (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Blackman C F, Benane S G and House D E (1987). ELF Electromagnetic Fields Cause Enhanced Efflux of Neutral Sugars from Brain Tissue in Vitro (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Blackwell R P (1986). Effects of Extremely Low Frequency Electric Fields on Neuronal Activity in Rat Brain. Bioelectromagnetics, Vol. 7 : 425-434.

Bowman J D, Peters J M et al (1987). Design for a Case-Control Study of Leukemia and ELF Electromagnetic Fields (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Bramlage L R, Weisbrode S M and Spurlock G E (1985). The Effect of Pulsating Electromagnetic Field on the Acute Healing of Equine Cortical Bone. Proc. of the Annual Convention, American Association of Equine Practitioners 1984 (published 1985), pp. 43-48.

Brand J S, Steiner M E et al (1986). Exposure of Chick Forebrain to ELF : Relation of Effects of Treatment, Experimental Replicates and Side of the Brain (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Brayman A A and Miller M W (1986). Induction of ELF Transmembrane Potentials in Relation to Power Frequency Electric Field Bioeffects in a Plant Root Model System. I. Relationship Between Applied Field Strength and Cucurbitaceous Root Growth Rates. Radiat. Environ. Biophys., Vol. 25 : 141-149.

Brighton C T and Pollack S R (1985). Treatment of Recalcitrant Non-Union With a Capacitatively Coupled Electric Field : A Preliminary Report. J. Bone and Joint Surgery, Vol. 67 : 577-585.

Brinkman K, Sander R et al (1987). Effects of Magnetic 50 Hz Fields on Tumor Cells and Peripheral Lymphocytes (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Brown D S, Gretz M et al (1986). Some Observations on the Effects of Applied Magnetic Fields on Growth of Avena Coleoptiles (ABSTRACT). Plant Physiology (United States), Vol. 80 : pp. 30.

Brulfert A, Miller M W et al (1985). A Cytohistological Analysis of Roots Whose Growth is Affected By a 60-Hz Electric Field. Bioelectromagnetics, Vol. 6 : 283-291.

Buchner J and Kleinebeckel D (1986). Muscle Reinnervation in Mice Under the Influence of Electromagnetic Fields (ABSTRACT). Pflugers Arch. Eur. J. Physiol., Vol. 406 (Supplement) : R28.

Burch J D, Craib K J P et al (1987). An Exploratory Case-Control Study of Brain Tumors in Adults. JNCI, Vol. 78: 601-609.

Byus, C V, Pieper S E et al (1987). The Effects of Low-Energy 60 Hz Environmental Electromagnetic Fields Upon the Growth-Related Enzyme Ornithine Decarboxylase : Possible Relation to Tumor Promotion (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Cadossi R, Ceccherelli G et al (1986). Effect of ELF Electromagnetic Fields on Lectin Induced Lymphocyte Proliferation (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Cain C D, Donato N J et al (1985). Pulsed Electromagnetic Field Modifies cAMP Metabolism and Ornithine Decarboxylase Activity in Primary Bone Cells. Conference on Electric and Magnetic Fields in Medicine and Biology (Conf. Publ. # 257) : 9-13.

Cain C D, Malto M C et al (1987). Effects of 60 Hz Fields on Ornithine Decarboxylase Activity in Bone Cells and Fibroblasts (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Chiabrera A, Bianco B et al (1987). Effect of DC and AC Magnetic Fields on Ligand Binding (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Chogovadze V A (1986). Use of L-Dopa and Travelling Pulsed Magnetic Field For the Treatment of Patients With Microcirculatory Dystonia. Klinicheskaya Med., No. 1 : 63-66.

Chuang H R, Chen K M and Lin C J (1986). Interaction of ELF_LF Electric Fields With Human Bodies and Metallic Objects (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Coggon D, Pannett B et al (1986). A Survey of Cancer and Occupation in Young and Middle Aged Men. II. Non-Respiratory Cancers. Brit. J. Indust. Med., Vol. 43 : 381-386.

Cohen M M (1986). The Effect of Low Level 60-Hz Electromagnetic Fields on Human Lymphoid Cells. II. Sister Chromatic Exchanges in Peripheral Lymphocytes and Lymphoblastoid Cell Lines. Mutation Research, Vol.172 : 177-184.

Cohen M M , Kunska A et al (1986). Effects of Low level, 60 Hz electromagnetic Fields on Human Lymphoid Cells : I. Mitotic Rate and Chromosome Breakage in Human Peripheral Lymphocytes. Bioelectromagnetics, Vol. 7 : 415-423

Coleman M, Bell C M J et al (1985). Leukemia and Electromagnetic Fields: A Case-Control Study. IEE International Conference on Electrical and Magnetic Fields in Medicine and Biology. Dec. 1985, London, England. Conf. Publ. No. 257 : pp. 122-125.

Conti R and Nicolini P (1985). Possible Biological Effects of 50 Hz Electric Fields : A Progress Report. Journal of Bioelectricity, Vol.4(1) : 177-193.

Cossarizza A, Bersani F et al (1987). Interleukin-2 and Cell Cycle-Related Gene Expression on Pulsed Electromagnetic Field (PEMF)-Exposed Cultures of Lymphocytes from Old Subjects (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Coulton L A, Barker A T et al (1985). An Investigation of Some Claimed Biological Effects of Electromagnetic Fields. International Conference on Electric and Magnetic Fields in Medicine and Biology (Conf. Publ. # 257) : 26-30

Creim J A, Lovely R H et al (1987). Exposure to a 35 KV/m HVDC Electric Field Does not Cause Avoidance Behavior in Rats Within the First 23 Hours of Exposure (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Creim J A, Lovely R H et al (1987a). Attempts to Produce Taste-Aversion Learning in Rats Exposed to HVDC Electric Fields (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Crick J C P (1985). Pacemaker-Dependent Patients and the Electromagnetic Fields They are Likely to Encounter. IEE Colloquium on Electromagnetic Interference and Cardiac Pacemakers. London, England, Jan. 1985. Digest No. 7. 3/1-3.

Dal Monte A, Fontanesi G et al (1985). Treatment of Congenital Psuedarthrosis and Aquired Non Union With Pulsing Electromagnetic Fields (PEMFs) : The Italian Trial (ABSTRACT). Orthop. Trans. Vol. 9 : 452-453.

Date M, Kaneko I et al (1986). Pulse Magnetic Stimulator for Biological Systems. Sci. Pap. Inst. Phys. & Chem Res. (Japan). 80(1) : 11-16.

Delgado, J M R (1985). Biological Effects of Extremely Low Frequency Electromagnetic Fields. Journal of Bioelectricity, 4(1) : 75-91.

Drenkard D V H, Gorewit R C et al (1985). Milk Production, Health, Behavior and Endocrine Responses of Cows Exposed to Electrical Current During Milking. J. Dairy Sci., Vol. 68 : 2694-2702.

Easley S P, Taylor L L et al (1987). Effects of Exposure to a 30 KV/m Electric Field on the Social Stress Behavior in Baboons (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Eckert E E (1977). Reply to "Sudden Infant Death Syndrome and Electromagnetic Fields. Point of View." Med. Klin., Vol. 72 : 871-874.

Enzler M A and Perren S M (1984). A Controlled Study of the Treatment of Non-Uniting Osteotomies with Pulsating Electromagnetic Fields. Orthopade, Vol. 13 : 97-101.

Etienne A S, Maurer R et al (1986). Short Distance Homing in the Golden Hamster after a Passive Outward Journey. Animal Behav., Vol. 34 : 696-715.

Formicki K and Winnicki A (1986). Incubation of Danube Salmon (Hucho hucho L) in Magnetic Field Beyond the Region of Its Natural Distribution. Bull. Pol.

Acad. Sci. Biol., Vol. 34 : 29-34.

Franceschi C, Bersani F et al (1986). Extremely Low Frequency Electromagnetic Fields (EMF) Affect Phytohemagglutinin (PHA) Induced Blastogenesis of Human Lymphocytes (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Frazier M E and Anderson L E (1987). Effects of 60-Hz Electric Fields on Immune Response in Rats (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Frykman G K, Taleismik J et al (1986). Treatment of Non-United Scaploid Fractures by Pulsed Electromagnetic Fields and Cast. J. Hand Surgery, Vol. 11A : 344-349.

Furness A and Lago B (1985). Factors that Influence the Susceptibility of Implanted Pacemakers to Interference by Electromagnetic Fields. IEE Colloquim on Electromagnetic Interference and Cardiac Pacemakers. London, England, Jan. 1985. Digest No. 7, 1/1-8.

Gallagher R P, Elwood J M et al (1985). Risk Factors for Ocular Melanoma. Western Canada Melanoma Study. JNCI, Vol. 74 : 775-778.

Gebhardt-Seehausen U and Recker S (1984). Reactions of Modern Cardiac Pacemakers to Interference Sources. Lebensversicherungsmedizin, Vol. 36 : 1-6.

Gilman P A, Ames R G et al (1985). Leukemia Risk Among US White Male Coal Miners. J. Occup. Med., Vol. 27 : 669-671.

Gmitrova A and Gmitrova G (1985). Some Aspects of the Biological Effects of Weak Electromagnetic Fields (ABSTRACT). Bohemoslov, Vol. 34(5) : 420.

Gold R G (1985). Clinical Evidence for Impairment of Pacemaker Performance by Electromagnetic Interference. IEE Colloquim on Electromagnetic Interference and Cardiac Pacemakers, London, England, Jan. 1985. Digest No. 7. 2/1-4.

Goodman E M and Greenebaum G (1985). A Review of Cell Effects Induced by Exposure of Extremely Low Frequency Electromagnetic Fields. In "Assessments and Viewpoints on the Biological and Human Health Effects of Extremely Low Frequency (ELF) Electromagnetic Fields". American Institute of Biological Sciences, Washington, ADA 156942 NTIS, Springfield, VA, pp 155-171.

Goodman R and Henderson A (1986). Effect of Low Frequency Electromagnetic Fields on translation (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Goodman R, Abbott J and Henderson A S (1987). Transcriptional Patterns in the X-chromosome of *Sciara Corophila* Following Exposure to Magnetic Fields. Bioelectromagnetics, Vol. 8 : 1-7.

Goodman R, Krim A J et al (1987a). Transcription and Translation in *Drosophila* Salivary Gland Exposed to Low Frequency Non-Ionizing Radiation (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Gorczyńska E and Wegrzynowicz R (1986). Magnetic Fields Provoke an Increase of Prostacyclin in Aorta of Rats. *Naturwissenschaften*, Vol. 43 : 675-677.

Gordon J M (1985). The Effects of Magnetic Fields on Avian Locomotion. PhD. Dissertation, Clemson University.

Gorewit R C, Scott N R et al (1985). Physiological Effects of Electrical Current on Dairy Cows. *Amer. soc. Agricultural Engineers*, Paper No. 85-3.

Greathouse D G (1985). Effects of Short Term, Medium Frequency Electrical Stimulation On Normal, Partially Denervated and Denervated Rat Skeletal Muscle. PhD. Dissertation, University of Kentucky.

Gustafson R J, Appleman R D et al (1986). Electrical Current Sensitivity of Growing/Finishing Swine for Drinking. *Transactions of the American Soc. for Agricultural Engineers*, Vol. 29 : Paper No. 14. pp. 620.

Gyuk I (1987). Analysis of Proximity for a Group of Baboons Exposed to a 30 KV/m 60 hz Electromagnetic Field (ABSTRACT). *Bioelectromagnetics Society 9th Annual Meeting*, June 1987.

Herbst E and Bryant C (1987). Influence of 72 Hz Sinusoidal Electromagnetic Field (EMF) on Wound Healing (ABSTRACT). *Bioelectromagnetics Society 9th Annual Meeting*, June 1987.

Hewson J J (1985). Variation in the Interference of VVI Cardiac Pacemakers. *IEE Colloquium on Electromagnetic Interference and Cardiac Pacemakers*, London, England, Jan. 1985. Digest No. 7. 3/ 1-3.

Ioale P, Papi F et al (1985). Pigeon Initial Orientation Effects of Oscillating Magnetic Fields of Different Shape and Frequency. *Tenth Meeting Italian Soc. of Animal Behavior*, October 1984.

Ionue M, Miller M W , Cox C and Carsteen E L (1985). Growth Rate and Mitotic Index Analysis of *Vicia Faba* L. Roots Exposed to 60-Hz Electric Fields. *Bioelectromagnetics*, Vol. 6 : 293-303.

Jackson S F (1986). The Effect of Pulsed Electromagnetic Fields and Dexamethasone on Tendon Cells in Culture (ABSTRACT). *Bioelectromagnetics Society 8th Annual Meeting*, June 1986.

Jackson S F and Bord S (1987). Mechanism of Direct Calcium Activation by Pulsed Magnetic Fields (ABSTRACT). *Bioelectromagnetics Society 9th Annual Meeting*, June 1987.

Jonas R B, Hejhall J et al (1986). Electromagnetic Pulse Radiation Effects on Natural Estuarine Microbial Communities of Chesapeake Bay USA (ABSTRACT). *86th Annual Meeting of Microbiology Society*.

Jones D B, Bolwell G P et al (1986). Amplification, By Pulsed Electromagnetic Fields, Of Plant Growth Regulator Induced Phenylalanine Ammonia-Lyase During Differentiation in Suspension Cultured Plant Cells. *Journal of Bioelectricity*, Vol. 5(1) : 1-12

Jones D B and Ryaby J T (1986). Low Frequency Electromagnetic Field Effects on cAMP and cAMP Dependent Protein Kinase Activity in Melanoma Cells (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Juutilainen J, Hari M et al (1986). Effects of 100 Hz Magnetic Fields with Various Waveforms on the Development of Chick Embryos. Radiat. Environ. Biophys. Vol. 25 : 65-74.

Juutilainen J and Saali K (1986a). Development of Chick Embryos in 1 Hz to 100 Hz Magnetic Fields. Radiat. Environ. Biophys. Vol. 25 : 135-140.

Kalmijn J A, Formicki K et al (1987). Biological effects of 5-Nanovolt/Centimeter Fields in Elasmobranch Fishes (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Karatchev I I and Kiev A N (1987). The Hygienic Significance of Electromagnetic Field Emitted by TV Stations.(ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Kitamura S, Iikura T et al (1985). Magnetic Field Detection in Chum Salmon Fry with Special Reference to the Magnetic Compass as Navigational Cue in Open-Sea Migration. Bull. Natl. Res. Inst. Aquacult., No. 8 : 31-42.

Klein K W (1984). Research Into the Effects of Exposure to High Voltage Electric Field. Amer. Soc. of Agricultural Engineers. Paper Presented at the 1984 Summer Meeting, Knoxville, Tennessee, June 24-27, 1984.

Klein K W (1985). The Effect of 60-Hz Electric Fields on Operant and Social Stress Behaviors of Non-Human Primates. Project Technical Status report to the Department of Energy, Report No. DOE/RA/50219-T5.

Klein K W (1986). The Effect of 60-Hz Electric Fields on Operant and Social Behaviors of Non Human Primates. Project Technical Status Report (Nov. 23-Jan 17, 1986) to the Department of Energy, Report No. DOE/RA/50219-T8.

Krauss W (1984). Magnetic Field Therapy and Magnetically Induced Electrostimulation in Orthopaedics. Orthopade, Vol. 13 : 78-92.

Kuterbach D A (1985). The Anatomy, Physiology and Development of Iron Containing Cells in the Worker Honey Bee (*Apis Mellifera*). PhD. Dissertation, State University of New York at Stony Brook.

Leal J, Trillo M A et al (1987). Embryonic Development and Magnetic Environment : Possible Role of Earth's Field Variations (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Leaper D J, Foster M E et al (1985). An Experimental Study of the Influence of Magnetic Fields on Soft Tissue Wound Healing. J. of Trauma, Vol. 25 : 1083-1084.

Lee J M, Burns A et al (1985). Electrical and Biological Effects of Transmission Lines : A Review. Report No. DOE/BP-524 submitted to the Department of Energy by the Bonneville Power Administration, Oregon, October, 1985 : 1-84.

Lee Q P, Guy A W et al (1987). The Effects of Modulated Radiofrequency Radiation on Calcium Efflux from Chick Brains in Vitro (ABSTRACT) Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Leung F C, Rommereim D N et al (1987). Effects of Electric Field on Rat Mammary Tumor Development Induced by 7,12-Dimethylbenz(A) Anthracene (DMBA) (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Liboff A R, Rozek R J et al (1987). Ion Cyclotron Resonance Tuning to Isotopic Frequency Modulated ^{45}Ca Incorporation in Human Lymphocytes (ABSTRACT) Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Liu L M, Cleary S F et al (1986). ELF Electric Field Effects on Tendon Fibroplasia in Vitro (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Lotz W G, Saxton J L et al (1986). Growth and Development of Rhesus Monkeys Exposed to ELF Electric and Magnetic Fields During the First 54 Months of Life. Final Report No. NAMRL-1318 to Naval Medical Research and Development Command, May 1986.

Lyle D B, Ayotte R D et al (1986). Inhibition of CTLL-1 Allogenic Cytotoxicity in the Presence of a 60 Hz Sinusoidal Electric Field (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Lyle D B, Ayotte R D and Adey W R (1987). Cyclosporin-A (CYA) and 12-O-Tetradecanoylphorbol-13-Acetate (TPA) Effects on a Murine Allogenic Mixed Lymphocyte Reaction in the Presence of a 60 Hz, 50 Gauss Pulsed Electromagnetic Field (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Maamarbachi O, Blondeau P et al (1986). Effects of Currents on Human Beings : Physical Pathology and Limits. Canadian Elec. Eng. J., Vol. 11 : 50-57.

MacLellan P and Stewart J M (1986). Latitudinal Gradients in Vegetation Along a Disturbed Transmission Line Right-of-Way in Manitoba. Canad. J. Botany, Vol. 64 : 1311-1320.

MacGinitie L A, Grodzinsky A J et al (1987). Protein Synthesis in Cartilage in Response to Applied Electric Fields (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Maffeo S, Miller M W et al (1984). Lack of Effect of Weak Low Frequency Electromagnetic Fields on Chick Embryogenesis. Journal of Anatomy, Vol. 139(4) : 613-618.

Mahmoud A A and Zimmerman D R (1984). Reproductive Performance of Pigs Exposed to High Voltage Electric Field. Second Generation. Amer. Soc. of Agricultural Engineers, Paper No. 84-3034.

Male J C (1985). Electromagnetic Field Conditions in the Vicinity of Power Transmission Lines and Possible Influences Upon Pacemaker Performance. IEE Colloquium on Electromagnetic Interference and Cardiac Pacemakers, London,

England, Jan. 1985. Digest No. 7. 5/ 1-3.

Male J C, Norris W T, Maddock B J and Bonnell J A (1985). Alternating Electric and Magnetic Fields Near Electric Power Equipment : Are they a Health Hazard? J. Soc. Radiol. Protection, Vol. 5 : 179-185.

Martin F B, Bender A et al (1986). Epidemiologic Study of Holstein Dairy Cow Performance and Reproduction Near a High Voltage Direct Current Powerhouse. J. Toxic. & Environ., Vol. 19 : 303-324.

Max Westby G W, Hopkins C D et al (1986). Scan Sampling: A New Model of a Waveform Recognition in Electric Fish (ABSTRACT). Neurosci. Letters, Suppl. S378.

McLaughlin J K, Walker H S R et al (1987). Occupational Risks for Intracranial Gliomas in Sweden. JNCI, Vol. 78 : 253-257.

Mooney N A, Smith R E et al (1986). Effect of Extremely Low Frequency Pulsed Magnetic Fields on Mitogenic Response of Peripheral Blood Mononuclear Cells. Bioelectromagnetics, Vol. 7 : 387-394.

Morris J E and McClanahan B J (1986). In Vitro Exposure of Lymphocytes to 60 Hz Electric and Magnetic Fields (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Murgatroyd P N (1985). Electromagnetic Fields Around Power System Inductors and Possible Methods of Reducing Them. Colloquium on Electromagnetic Interference and Cardiac Pacemakers. Digest No. 7, Vol. 6 : 1-6

Myers A, Cartwright R A et al (1985). Overhead Power Lines and Childhood Cancer. IEE International Conference on Electrical and Magnetic Fields in Medicine and Biology, Dec. 1985, London, England. Conf. Publ. No. 257 : 120-130.

Nordenson I and Hansson Mild K (1987). Clastogenic Effects of Low Intensity Magnetic Fields (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Nordenson I and Hansson Mild K (1987a). Cytogenetic Studies of Human Lymphocytes After Exposure to Transient Currents (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Niemi G J and Hanowski J M (1986). Assessing the Effect of the ELF Antenna System on Breeding Bird Communities (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Orr J L, Smith H D et al (1987). Effects of 30 KV/m Electric Fields on the Operant Behavior of the Non-Human Primates (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Phillips J B (1986). Two Magnetoreception Pathways in a Migratory Salamander *Notophthalmus-Viridescens*. Science, Vol. 233 : 765-767

Phillips J L (1986). Transferrin receptors and Natural Killer Cell Lysis. A Study

Using Colo 205 Cells Exposed to 60 Hz Electromagnetic Fields. Immunology Letters, Vol. 13 : 295-299.

Phillips R (1986). Overview of WHO Environmental Health Criteria 35 on Extremely Low Frequency (ELF) Fields. National Technical Information Service, July 1986.

Phillips J L, Ruthledge L and Winters W D (1986). Transferrin Binding to Two Human Colon Carcinoma Cell Lines : Characterization and Effects of 60 Hz Electromagnetic Fields. Cancer Res. Vol. 46 : 239-244.

Phillips J L, Winters W D and Ruthledge L (1986a). In Vitro Exposure to Electromagnetic Fields : Changes in Tumor Cell Properties. Int. J. of Radiation Biology, 49(3) : 463-469.

Quinlan W J, Thomson R A E et al (1986). Neuroendocrine Response of Cannulated Rats to Intermittent 60 Hz Electric Fields (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Quinlan W J, Thompson R A E et al (1987). Neuroendocrine Response of Cannulated Rats Exposed to Intermittent or Ramped 60 Hz Electric Fields (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Raleigh R J (1987). Joint HVDC Agricultural Study : Annual Progress Report for the 1986 Study Period. Report submitted to Bonneville Power Administration, Portland, Oregon. Contract No. DE A179-85BP 21216.

Reese J A, Jostes R F et al (1987). Exposure of Human Lymphocytes to 60 Hz AC EMF: Alkaline Elution Analysis of DNA Damage and Repair (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Reilly J P and Larkin W D (1985). Human Reactions to Transient Electric Currents - Summary Report. John Hopkins Univ./ APL Report PPSE T-34, June 1985.

Rein, G, Korins K et al (1987). Inhibition of Neurotransmitter Uptake in Neuron Cells by Pulsed Electromagnetic Fields (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Rogers W R (1986). Additional Dependent Variables Which Should Be Assessed in Planned Non-Human Primate Studies of 60-Hz Electric Fields. Department of Energy Project Report No. DOE/RA/50220-T7.

Rogers W R, Lucas J H et al (1985). Effects of 60-Hz Electric Fields on Operant and Social Stress Behaviors in Non-Human Primates. Department of Energy Contractor's Conference, Alexandria, VA, November 5, 1985.

Rogers W R, Lucas J H et al (1986). 60-Hz Electric Fields Do Not Serve as a Negative Reinforcer in Non-Human Primates (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Rogers W R and Smith H D (1987). Effect of 30 KV/m Electric Field Upon the Baboons Postures and Positions (ABSTRACT). Bioelectromagnetics Society 9th

Annual Meeting, June 1987.

Roy W R and Lee J M Jr. (1984). Transmission Line Impacts on Agriculture : Issues and Research. Amer. Soc. of Agricultural Engineers , Paper No. 84- 3033.

Rumsey J W (1985). A Methodology for Developing Agriculture Impact Reports for Proposed High Voltage Transmission Lines. Amer. Soc. of Agricultural Engineers, Paper No. 85-3528.

Ryaby J T , Jones D B et al (1986). Protein Phosphorylation and Synthesis in Melanoma Cells is Affected by Low Frequency Electromagnetic Fields (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Ryaby J T, Jones D B et al (1987). A Proposed Mechanism of Action of LOW Frequency Electromagnetic Fields on Melanoma Cells (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Sakharova S A, Ryzhov A I et al (1977). Reaction of Central and Peripheral Mediator Elements of the Sympathoadrenal System to Single Exposure to Alternating Magnetic Field. Biologicheskie Nauki, No. 9 : pp 35-39.

Savitz D A, Wachtel H et al (1986). Case-Control Study of Childhood Cancer : Residential Exposure to EM Fields : Incidence and Risk, Epidemiology (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Seto Y J, Majeau-Chargois D et al (1986). Chronic 60 Hz Electric Field Exposure Induced Subtle Bioeffects on Hematology. Environmental Res. Vol. 39 : 143-152.

Sheppard A R, Goodman A J et al (1987). Statistical Characteristics of the Activity of 60 Hz Electric Field Exposed Aplysia Pacemaker Neurones (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Sisken B F, Fowler I et al (1986). Pulsed Electromagnetic Fields and Normal Chick Development. Journal of Bioelectricity, Vol. 5(1) : 25-34.

Sisken B F, Ringham G and Dyer S (1985). Nerve Regeneration in Vitro : Comparative Effects of Direct and Induced Current and NGF (Nerve Growth Factor). Final Report to the Office of Naval Research on Contract N00014- 82-K-0105 (Filed 11/26/85).

Soldatchenkov V N and Kiev A N (1987). Protection of Environment from the Influence of Nonionizing Radar Exposure (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Stell M, Sagan P M et al (1987). A Behavioral Test of Cyclotron Resonance Theory (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Stevens R G (1986). Epidemiological Studies of Cancer and Residential Exposure to Electromagnetic Fields. Final report: Power Lines Project 21082-18, November 1986.

Stollery B T (1986). Effects of 50 Hz Electric Currents on Mood and Verbal Reasoning Skills. *British J. Indust. med.*, Vol. 43 : 339-349.

Takahashi K, Kaneko I, Date M and Fukuda E (1985). Effect of Pulsing Electromagnetic Fields on DNA Synthesis in Mammalian Cells in Culture. *Experientia*, Vol. 42 : 185-186.

Teyssedre A (1986). Radiotracking of Pigeons Previously Exposed to Random Oscillating Magnetic Fields. *Behavior*, Vol. 96 : 265-276.

Thomas J R, Schort J and Liboff A (1985). Investigation of Potential Behavioral Effects of Exposure to 60-Hz Electromagnetic Fields. Naval Medical research Institute Final report AD-A169 650, NMRI 85-63 : pp. 72-

Thomas J R, Schort J et al (1986). Low Intensity Magnetic Fields Alter Operant Behavior in Rats. *Bioelectromagnetics*, Vol. 7 : 349-357.

Thomas T L and Waxweiler R J (1987). Brain Tumors and Occupational Risk Factors : A Review. *Scand. J. Work Environ. Health*. Vol. 12 : 1-15.

Timms W E (1985). Nuclear Magnetic Resonance (NMR) Imaging Systems and the Possible Influence of the Magnetic Environmental Conditions on Pacemaker Performance. IEE Colloquim on Electromagnetic Interference and Cardiac Pacemakers. London, England, Jan. 1985. Digest No.7. 9/1-2.

Tomashevskaja L A and Solenyi E A (1986). Biological Action and Hygienic Significance of the Electromagnetic Field Created by Coastal Radar Facilities. *Gig. Sanit. (USSR)*, Vol. 7 : 34-36.

Tomenius L (1986). 50 Hz Electromagnetic Environments and the Incidence of Childhood Tumors in Stockholm County. *Bioelectromagnetics*, Vol. 7 : 191- 208.

Tompkins, W A F, Lockwood J F et al (1985). Immunological Effects of Extremely Low Frequency Electromagnetic Fields. In " Assessments and Viewpoints on the Biological and Human Health Effects of Extremely Low Frequency (ELF) Electromagnetic Fields". American Institute of Biological Sciences, Washington, ADA 156942 NTIS, Springfield, VA, pp 365-382.

Vresilovic E J, Pollack S R et al (1985). Theoretical Determination of Electric Fields and Current Densities in Long Bone Fractures During 60-KHz Electrical Stimulation with Skin Electrodes. International Conference on Electric and Magnetic Fields in Medicine and Biology. Conf. Publ. No. 257 : 44-48.

Wachtel H, Barnes F and Savitz D (1986). The Predominant Statistical Influence of Outside Sources in Producing Non-Appliance ELF Fields in Homes (ABSTRACT). Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Winters W D (1986). Biological Functions of Immunologically Reactive Human and Canine Cells Influenced by In Vitro Exposure to 60 Hz electric and Magnetic Fields. Final Report to New York State Power Lines Project, Albany, 1986.

Winters W D, Brune J L et al (1986). Virus Suppressor Factors Induced in Cultured Cells by Exposure In Vitro to 60 Hz AC Magnetic Fields (ABSTRACT).

Bioelectromagnetics Society 8th Annual Meeting, June 1986.

Zecca L, Dal Conte G et al (1985). The Effect of Alternating Magnetic Fields on Experimental Inflammation in the Rat. Bioelectrochemistry and Bioenergetics, Vol. 14 : 39-43.

Zecca L and Ferrario P (1987). Effects of Alternating Magnetic Fields on Chronic Inflammation in the Rat (ABSTRACT). Bioelectromagnetics Society 9th Annual Meeting, June 1987.

Zerwekh J E, Nicar M J, Shimizu T and Stith W J (1986). The Effect of Pulsed Electromagnetic Fields on the Corrosion of Chromium-Cobalt-Nickel Alloy Orthopedic Implants. Biomaterials, Vol. 7 : 243-246.

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